Adaptation to rapid land-use and climate changes on the Yamal Peninsula, Russia: Remote sensing and models for analyzing cumulative effects
Grant NNX09AK56G

Final Report, 30 Jun 2013

D.A. Walker, U.S. Bhatt, M. Buchhorn, H.E. Epstein, B.C. Forbes, Birgit Heim, M.O. Liebman, M.K. Raynolds, G.V. Frost, Q. Yu

Table of Contents

1 Abstract

This report summarizes four years of research for the NASA-LCLUC project entitled "Adaptation to rapid land-use and climate changes on the Yamal Peninsula, Russia: Remote sensing and models for analyzing cumulative effects" (NASA Grant No. NNX09AK56G). It includes summaries of field work conducted in the summers of 2009, 2010, 2011, and 2012 project workshops in Rovaniemi, Finland in March 2010 and May 2012, work completed on the major components of the study, and a list of publications to date. The project was part of an International Polar Year (IPY) initiative called "Greening of the Arctic" (GOA) and the Northern Eurasia Earth Sciences Initiative (NEESPI). Our objective was to address circumpolar changes in Arctic vegetation productivity and the relevance of climate change and resource development to the indigenous Nenets people in northwest Siberia and elsewhere in the Arctic. Over 40 investigators and students were involved in the research from the University of Alaska Fairbanks, the University of Virginia, NASA Goddard, the Earth Cryosphere Institute (ECI) in Tyumen and Moscow, Russia, the Arctic Centre (AC) in Rovaniemi, Finland, and the Alfred Wegener Institute, Potsdam, Germany. There were four major sets of observations and findings derived from these projects:

Climate-change studies. Strong correlations between coastal summer sea-ice trends, land-surface-temperatures (LST), and vegetation greenness (using the Normalized Difference Vegetation Index, NDVI) were found for most Arctic regions and the circumpolar Arctic as a whole (Forbes et al. 2009, Walker et al. 2009, Forbes et al. 2010, Bhatt et al. 2010a, Walker et al. 2011a, 2011d, Kumpula et al. 2011, Goetz et al. 2011, Kumpula et al. 2012, Macias-Fauria et al. 2012, Parmentier et al. 2013). Recent studies have found a divergence of temperature and NDVI trends in Eurasia vs. North America (Walker et al. 2012d). Further research is needed to partition the drivers underlying this heterogeneity to further our understanding and modeling of how future changes will play out as the ongoing warming continues (Dutrieux et al. 2012).

Environmental and remote-sensing studies along the Eurasia Arctic Transect (EAT) and the North America Arctic Transect (NAAT). Six expeditions to the Yamal Peninsula and Franz Josef Land (including those from a previous round of NASA LCLUC funding) produced a rich integrated dataset of vegetation, soil, active layer, permafrost temperature, and spectral information from the EAT (Walker et al. 2009, 2011a, Heim et al. 2011, Epstein et al. 2012). Remote-sensing studies examined the regional effects of climate, terrain, permafrost, soil, and disturbances on the EAT land surface (Raynolds et al. 2008, Raynolds and Walker 2009, Raynolds et al. 2011, Epstein et al. 2012, Frost et al. 2013, Buchhorn et al. 2013). The study found strong heterogeneity in productivity changes across the climate gradient related to summer temperatures, reindeer grazing, soil texture. Major differences in the temporal changes were seen in continental areas of the NAAT compared to the more maritime EAT.

Vegetation change modeling. The field observations from the EAT were used to *improve the parameterization of the ArcVeg model* so it is suitable for vegetation-change studies in tundra regions. Specifically, it models changes in the biomass and productivity of different plant functional types using different scenarios of changing summer warmth, soil substrates, and reindeer foraging (Yu et al. 2009, Epstein et al. 2007, Goetz et al. 2011, Yu et al. 2011).

Cumulative effects of resource development and climate change. Several publications examined the relationships of hydrocarbon development to Nenets land-use (Walker et al. 2009, Stammler and Forbes 2007, Forbes and Stammler 2009, Forbes et al. 2010, Kumpula et al. 2011) and the causes and effects of landslides in the region of intensive development near

Bovanenkovo (Leibman et al. 2008, Khomutov et al. 2009). Recent efforts have expanded the investigations on the Yamal to comparative studies of the Prudhoe Bay Oilfield in Alaska (Raynolds et al. 2013, 2012a, Walker et al. 2012b). The project web site has complete results from the previous rounds of funding, including past proposals, publications, posters and talks at conferences and workshops, annual data reports, annual reports to NASA, and list of participants (http://www.geobotany.uaf.edu/yamal/index).

2 Study objectives and significance

Our principal goal was to develop a comprehensive hierarchical understanding of the cumulative effects of resource development, climate-change, and traditional land use on the Yamal Peninsula, Russia and elsewhere in the Arctic. To accomplish this we employed a combination of field observations, models of climate/ vegetation change and social-ecological analyses.

The Yamal Peninsula in northern Russia has undergone extensive anthropogenic disturbance and transformation of vegetation cover over the past 20 years due to gas and oil development and grazing by the Nenets reindeer herds. It has been identified as a “hot spot” for both Arctic climate change and land-use change. The complex interactions between a rapidly changing climate, expanding resource development, and constantly evolving social, economic and political environments make it clear that more sophisticated models and approaches are needed to help in planning for the future of the Yamal.

We used remote-sensing and modeling to examine how the terrain and anthropogenic factors of reindeer herding and resource development, combined with the climate variations on the Yamal Peninsula, affect the spatial and temporal patterns of vegetation change and how those changes are in turn affecting traditional herding by indigenous people of the region. The tools developed here will also serve to examine similar changes that are occurring elsewhere in the Arctic and help the indigenous people adapt to the impending changes.

3 Major accomplishments in 2009-2012

3.1 Field work in 2009 and 2010: Ostrov Belyy and Krenkel, Eurasia Arctic Transect

One of the goals of the goals was to examine the trends in vegetation, soils, permafrost characteristics and surface spectral properties along a complete Arctic transect in Russia. The Eurasia Arctic Transect (EAT, Fig. 1) stretches from Nadym at 65° 19’ N to Krenkel Station in Franz Josef Land at 80° 38’ and consists of seven study locations in all five of the Arctic bioclimate subzones and the forest-tundra transition**.** This transect is similar in concept to the North America Arctic Transect (Walker et al. 2008). During the previous round of LCLUC funding we characterized the landscapes at Nadym, Laborovaya, Vaskiny Dachi, and Kharasavey. In July 2009, we visited Ostrov Belyy and Kharp in July 2009 and in August 2010, the Krenkel Hydro-meteorological Station in Franz Jozef Land (Fig. 1). Data reports from all four NASA-GOA Russia EAT expeditions in 2008-2010 are available online at http://www.geobotany.uaf.edu/yamal/reports.

The 2010 expedition to Hayes Island in the Franz Josef Land Archipelago completed the Eurasia Arctic Transect (EAT) and was one of the high points of the Russian research because so little was known about terrestrial environments. The 2011 Krenkel data report presents the vegetation, remote sensing and environmental data collected in 2010 near Krenkel Station. The studies followed the same basic procedures used at the locations visited in 2007-2009. The data report includes: (1) a general description of the location and study sites with photographs, (2) maps of the study sites, study plots, and transects at each location, (3) tabular summaries of the vegetation, site factors, and soils at each relevé, (4) summaries of the Normalized Difference Vegetation Index (NDVI) and leaf area index (LAI) along each transect, (5) detailed soil descriptions and photos of the large soil pits at each study site, (6) contact information for each of the participants. The expedition also established the farthest north permafrost and active-layer monitoring site. The appendices to the report include: Appendix A — Names and addresses of the participants in all four expeditions; Appendix B — Plot and soil photographs from all study sites; and Appendix C — List of birds observed at Krenkel Station and along the route of the ship during 28 Jul to 2 Aug. (available at the web site: http://www.geobotany.uaf.edu/library/reports/yamal_2009_dr091212embDRAFTa.pdf.

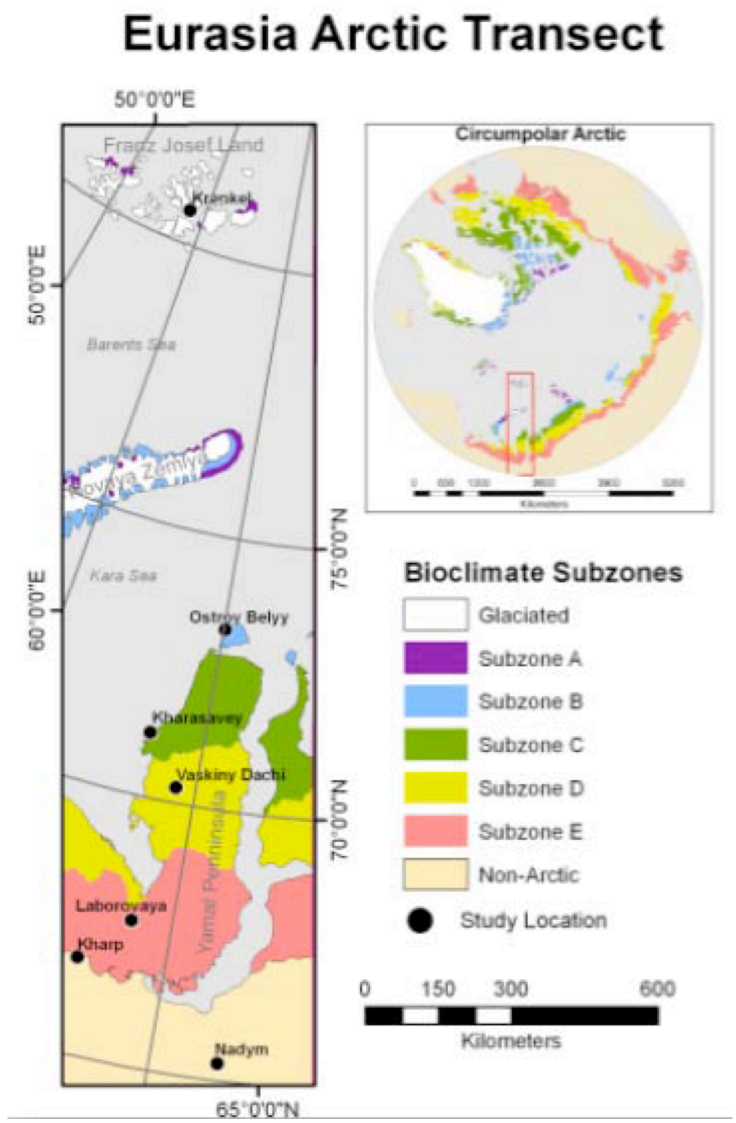

Figure 1. *Eurasian Arctic Transect Bioclimate subzones are according to CAVM Team (2003). The seven EAT study locations are also shown.*

3.2 Fieldwork in 2011 and 2012: Shrub expansion at Kharp, and Vaskiny Dachi Russia

In 2011 and 2012, fieldwork was focused at Kharp in the in foothills of the Polar Urals (Fig. 1). Kharp is the primary study site of G. V. Frost's Ph.D. dissertation research at the University of Virginia to elucidate the relationship of post-1968 shrub expansion to disturbance at the landscape-scale (fire) and the meter-scale (cryogenic processes). Previous evaluation of 1960s-era Corona satellite imagery indicated that alder shrubland extent has increased markedly at the site in recent decades. This finding was corroborated by pixel-based linear regression of the Normalized Difference Vegetation Index (NDVI), derived from Landsat time-series spanning 1985-2010 that indicate strong increases in plant productivity ("greening"), especially in association with alder shrublands. The field studies were aimed at understanding the causes of the changes. A data report fully describes the site, climate, disturbance history, methods used in sampling the vegetation and soils, and results. Six appendices provide: (1) the list of participants, (2) soils descriptions of the study sites, (3) Plant species cover-abundance in the vegetation study plots, (4) birds observed, (5) soil physical and chemical characteristics, and (6) photos of the Kharp transect, July-August 2011. In 2012, the Kharp site was revisited to retrieve temperature loggers, and place additional loggers. The data report is available at the website: http://www.geobotany.org/library/reports/FrostGV2012_yamal_dr20121030.pdf.

Also in summer 2011, we completed an intensive study of azonal habitats at Vaskiny Dachi in the central Yamal Peninsula. We will examined the shrub vegetation, lichen heathlands, and a wetland to help in the remote sensing interpretations of the peninsula and to examine disturbed habitats.

3.3 Second and Third Yamal Land-Cover Land-Use Change Workshops, Rovaniemi, 8-10 Mar 2010 and 19-21 May 2012.

The Second Yamal Land-Cover Land-Use Change Workshop was attended by 22 participants at the Arctic Centre, Rovaniemi, Finland, 8-10 March 2010. The overall objectives were to (1) review the goals of the project; (2) discuss the progress of each of the individual parts of the project; (3) adjust the goals in light of new discoveries, changing funding situation, and changing personnel; (4) discuss the 2010 and 2011 summer field seasons; (5) plan new publications and research; and take advantage of the special opportunity to meet with collaborators in NASA (Joey Comiso and Jorge Pinzon). A total of 30 presentations were made at the meeting. The papers presented at the meeting are on the project web site: (http://www.geobotany.uaf.edu/yamal/rovMtg/posters).http://www.geobotany.uaf.edu/yamal/rovMtg/agenda.

The Third Yamal Yamal Land-Cover Land-Use Change Workshop was attended by 13 participants at the Arctic Centre, Rovaniemi, Finland, 19-21 May 2012. The dates and location have been chosen to take advantage of the timing of the 12th International Circumpolar Remote Sensing Symposium, Levi, Finland, where several members of the project presented papers. The Finland location also allowed several Russian participants to travel to the meeting. The agenda and talks presented at the workshop are at the website: http://www.geobotany.uaf.edu/yamal/rovMtg2/posters.

In addition, we have made presentations at several other conferences and workshops including the 2009, 2010, 2011, and 2012 LCLUC All Scientists meetings (unpublished talks and posters citations 31-43), the Fall AGU meetings in San Francisco (Dec 2009, 2010, 2011, and 2012), the State of the Arctic Meeting in Miami (Mar 2010), the IPY Oslo Science Conference (Jun 2010), the 12th Circumpolar Remote Sensing Symposium, Levi, Finland (May 2012), the 10th International Conference on Permafrost, Salekhard, Russia (Jun 2012), and the Arctic Science Summit Week (April 2013).

4 Summaries of major findings from the each component of the project:

4.1 Climate change studies (Uma Bhatt, Skip Walker, Martha Raynolds, Jiong Jia, Howie Epstein, Jorge Pinzon, Joey Comiso).

Until recently, trends in sea ice retreat have generally corresponded with increases in summer warmth and tundra greening in most regions of the Arctic (Bhatt et al. 2010b). However, when the analysis was extended to 1982-2011 there are several notable differences from the earlier period (Figure 2) particularly for land surface temperatures. There is a larger area of cooling over western Eurasia and there is cooling over the southern tundra areas in North America, which had been warming in the earlier period. Open water (sum of weekly open water in % from May-Aug) during summer has increased everywhere in the coastal Arctic with the largest increases in Beringia and Kara-Barents Sea (Figure 2).

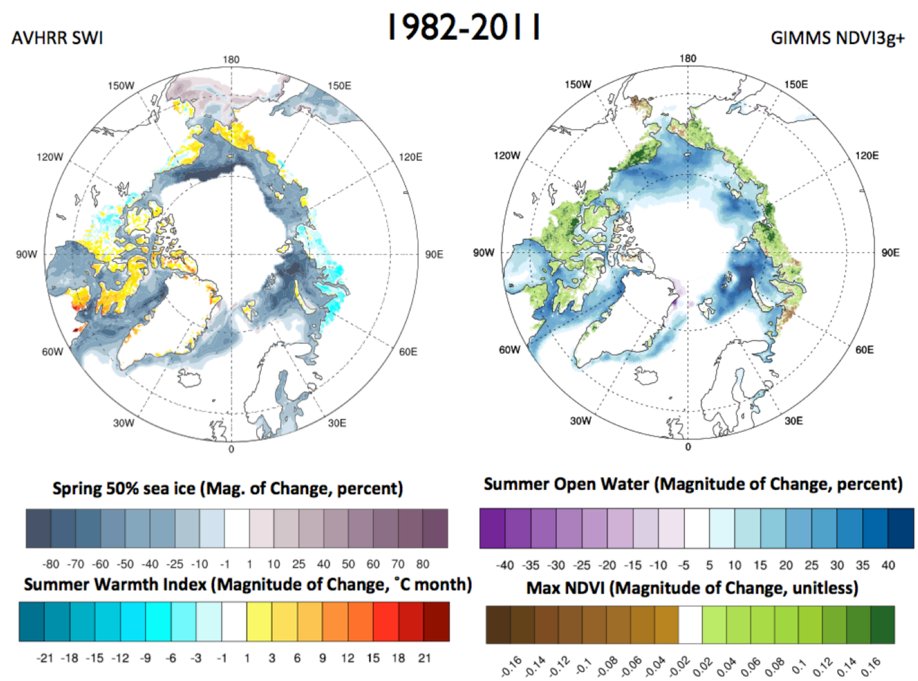

Figure 2. *Magnitude of 1982-2011 trends in spring sea ice (left panel), SWI (left panel), summer open water (right panel), and MaxNDVI (AVHRR GIMMS3g+ (right panel). Figure in Walker (2012a) and updated from Bhatt (2010).*

The Normalized Difference Vegetation Index (NDVI) has also generally increased over the Arctic tundra domain from 1982-2011, however there are several areas where NDVI (e.g. SW Alaska, Chutoka, and Coastal West Kara Sea) and SWI (e.g. parts of central Asia between 60-120E) where the NDVI has decreased.

The land warming and MaxNDVI increase is larger over North America than Eurasia (Figures 3-4). SWI has flattened out over the past decade in North America and is actually showing cooling over Eurasia (Figure 4). Coastal sea ice decreases have been larger over Eurasia than North

America (Figure 4) for the full period. Trends are diverging in NDVI between North America and Eurasia after 2001 (Figure 3) (Walker et al. 2012d). Intra-seasonal analysis suggests that midsummer temperatures are cooling and analysis thus far suggests a link to changes in summer convection (Bhatt et al. 2012).

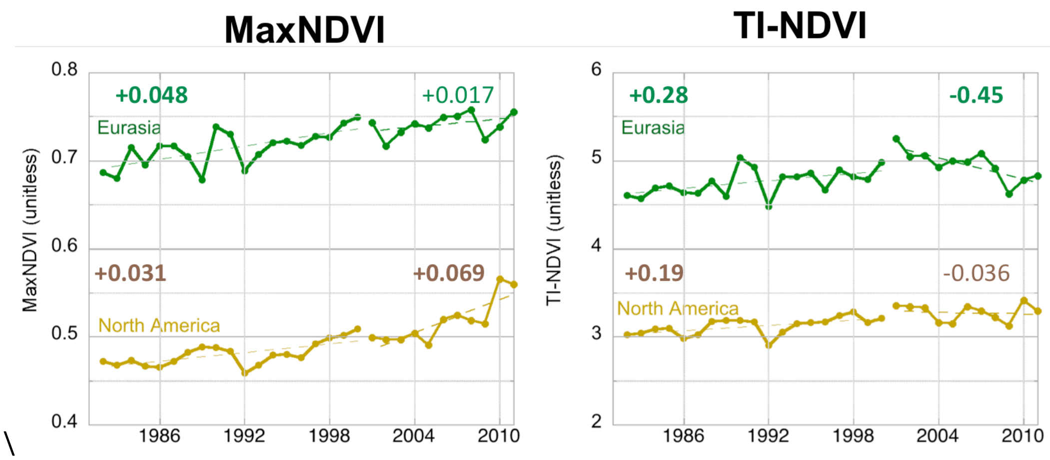

Figure 3. *AVHRR GIMSS3g+ MaxNDVI (left) and TI-NDVI (right) during summer from 1982 to 2011 over the full tundra domains. Trends are largest for North America while the mean is larger in Eurasia. The trends are not constant over time and change after 2001. Trend magnitudes are shown above each line segment for the period over which the trend was calculated. Updated from Bhatt et al. (2010) and presented in Bhatt et al. (2012b).*

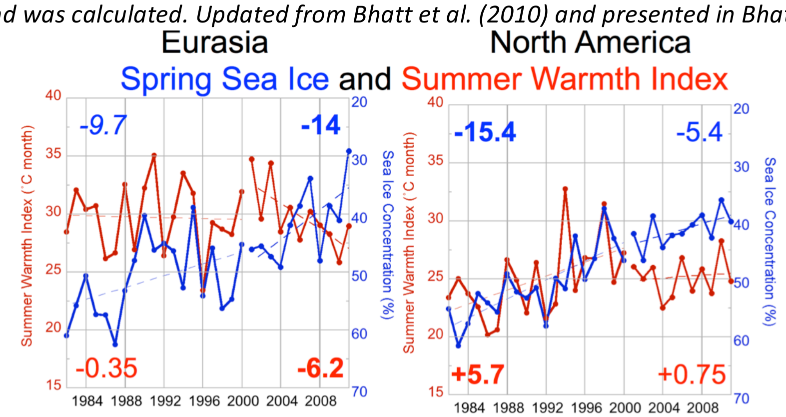

Figure 4. *Spring sea ice (blue) and SWI (red) for Eurasia (left) and North America (right) from 1982 to 2011 over the full tundra domains. The trends are not constant over time and change after 2001. Trend magnitudes are shown above each line segment for the period over which the trend was calculated. Updated from Bhatt et al. (2010) and presented in Bhatt et al. (2012b).*

4.2 Environmental and remote-sensing studies along the Eurasia Arctic Transect (EAT) and the North America Arctic Transect (NAAT).

4.2.1 Ground measurements of NDVI, LAI, and biomass (Howie Epstein, Skip Walker, G.V. Frost, Marcel Buchhorn, Birgit Heim)

NDVI, LAI, and biomass trends have now been determined for the entire Eurasia transect. We developed a comprehensive, synthetic dataset of field observations for vegetation and soil properties along the full bioclimate gradient in North America and Eurasia. Information from the EAT is in the process of analysis (Walker et al. 2011b) and we anticipate a vegetation manuscript similar to that published for the North America transect (Walker et al. 2011c).

Among the findings is a remarkably similar relationship between zonal landscape-level aboveground biomass and AVHRR-derived NDVI along both transects (Fig. 5). However, despite the almost identical relationships between biomass and NDVI, the Eurasia transect has distinctly higher hand-held NDVI values for equivalent biomass and LAI (Fig. 6a and b).

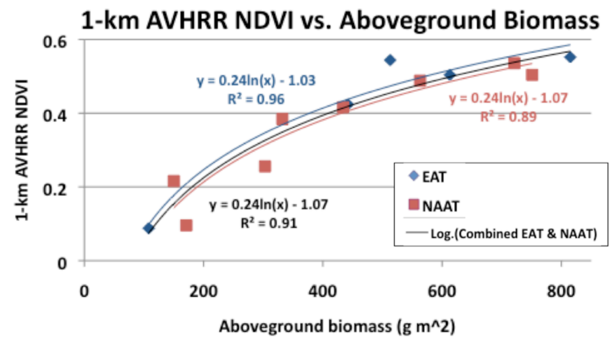

Figure 5. *Relationship between AVHRR NDVI and landscape-level zonal aboveground biomass along the North America (NAAT) and Eurasia Arctic (EAT) transects (Raynolds et al. 2012).*

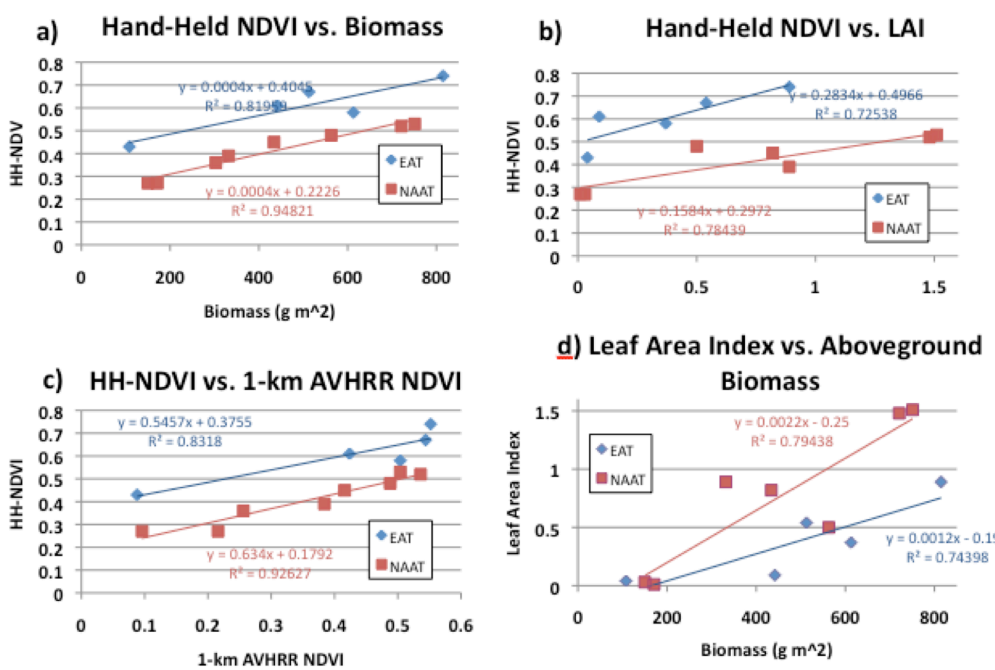

Figure 6. *Trends in ground-based meassurements of biomass and LAI vs. NDVI along the North America and Eurasia transects. (a) Hand-held (HH) NDVI vs total aboveground biomass. (b) HH NDVI vs. leaf area index. (c) HH NDVI vs. 1-km AVHRR NDVi. (d) Leaf area index vs. biomass. The distinctly different trends for the two transects reflect differences in the plant-canopy structure along the two transects (Epstein et al. 2012).*

Similarly, the hand-held NDVI values are higher for equivalent AVHRR NDVI values along the EAT than along the NAAT (Fig. 6c). Most interesting is the diverging trend lines of LAI vs. biomass along the two transects (Fig. 6d), with higher LAI values along the NAAT. The differences in the trend lines are attributed to differences in plant canopy structure caused by a variety of factors including different precipitation regimes, glacial histories, soils and grazing regimes, which alter the relative proportions of different plant growth forms (Walker et al. 2012a, Epstein et al. 2012, Raynolds et al. 2012b).

4.2.2 Hyperspectral and goniometer studies along the EAT and NAAT (Marcel Buchhorn and Birgit Heim)

Field spectral measurements combined with hyperspectral airborne data, such as those obtained from the AVIRIS spectrometer, or satellite data (such as those from the proposed NASA HyspIRI Mission) may allow us to identify tundra vegetation dynamics at the resolution of individual plant communities. Field spectroscopy measurements were made at many of the plots in North America, Canada, and Russia (Jia et al. 2002, 2004, Walker et al. 2012a, Frost et al. 2013, Epstein et al. n.d.). Additionally, in the summer of 2012, broadband and hyperspectral vegetation indices were examined along the main environmental gradients (climate, soil pH, soil moisture) of the EAT at Vaskiny Dachi and of the NAAT at Happy Valley, Sagwon, Franklin Bluffs, and Deadhorse. These were collected in anticipation of the European EnMap mission (Heim et al. 2011, Buchhorn and Schwieder 2012, Buchhorn et al. 2013), and would also be available for the planned NASA ABoVE studies in Alaska (Kasischke et al. 2010). Ground-based hyperspectral characterization of Low Arctic Alaskan tundra communities were obtained along four environmental gradients (regional climate, soil pH, toposequence, and soil moisture) that all vary in ground cover, biomass and dominating plant communities. Spectral metrics were extracted, including the averaged reflectance and absorption-related metrics such as absorption depths and area of continuum removal. The spectral metrics were investigated with respect to 'greenness,' biomass, vegetation height, and soil moisture regimes. The results show that the surface reflectance is similar in shape at all sites with a reduced NIR reflectance that is specific for low-growing biomes. The main spectro-radiometric findings are: i) Southern sites along the climate gradient have taller shrubs and greater overall vegetation biomass, which leads to higher reflectance in the NIR. ii) Vegetation height and surface moisture are two antagonists that balance each other out with respect to the NIR reflectance along the toposequence and soil moisture gradients. iii) Moist acidic tundra (MAT) sites have 'greener' species, more leaf biomass, and green-colored moss species that leads to higher pigment absorption compared to moist non-acidic tundra (MNT) sites. iv) MAT and MNT plant community separation via narrowband NDVI show the potential of hyperspectral remote sensing applications in the tundra.

In collaboration with scientists from the Alfred Wegner Institute in Potsdam, we are also

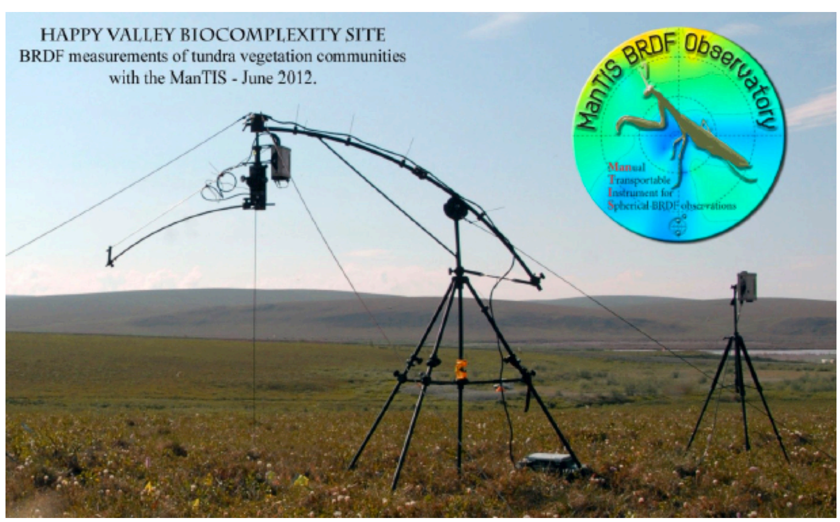

***Figure 7**. The ManTIS field portable spectro-goniometer of the AWI. This transportable, field goniometer is the first of its kind and is adapted for use in Arctic field conditions. Picture by M. Buchhorn.*

examined how vegetation indices of different vegetation types are affected by changing solar incident angles during the growing season and by different viewing angles of the satellites. This is an especially important topic in the Arctic where the solar incident angles are high and vary strongly through the short growing season. In 2012, we collected *bidirectional reflectance distribution function (BDRF)* data of zonal vegetation at the key NAAT locations at Happy Valley, Franklin Bluffs and Deadhorse with a new portable field gonio-spectrometer (ManTIS BRDF Observatory®, patent pending – DE 102011117713.6) (Fig. 7). These data can be used for BRDF normalization of satellites with a broad imagery-acquisition swaths (e.g. AVHRR, MODIS, MERIS, LANDSAT) or sensors with off-nadir pointing capabilities (e.g. EnMAP, GeoEye).

4.2.3 Remote sensing of land use land-cover change (Howie Epstein, Skip Walker, Timo Kumpula, Bruce Forbes, Gerald Frost, Qin Yu, Hilmar Maier)

4.2.3.1 Bovanenkovo, Yamal Peninsula (Timo Kumpula)

We accomplished several projects related to the remote sensing of land-use land-cover change on the Yamal Peninsula and other regions of Siberia and North America. We used Quickbird, ASTER, SPOT, and Landsat imagery to examine the social and environmental impacts of development at the Bovanenkovo gas field in central Yamal on the tundra and its relation to the Nenets reindeer herders (Kumpula et al. 2012). We are continuing with this effort to use high and very high resolution satellite imagery to examine the effects of development on surface properties of the adjacent tundra, including surface temperatures, albedo, normalized difference vegetation index (NDVI) and normalized difference water index (NDWI).

4.2.3.2 Nadym and Kharasevey (Qin Yu)

In addition to conducting further analyses of Bovanenkovo (Kumpula et al. 2011), we have expanded the scope of this effort to include gas extraction sites at Nadym and Kharasavey. We have also begun to use the Landsat Decadal Survey imagery to develop land-cover-change maps for the entire Yamal Peninsula, (Maier and Walker 2010a, 2010b).

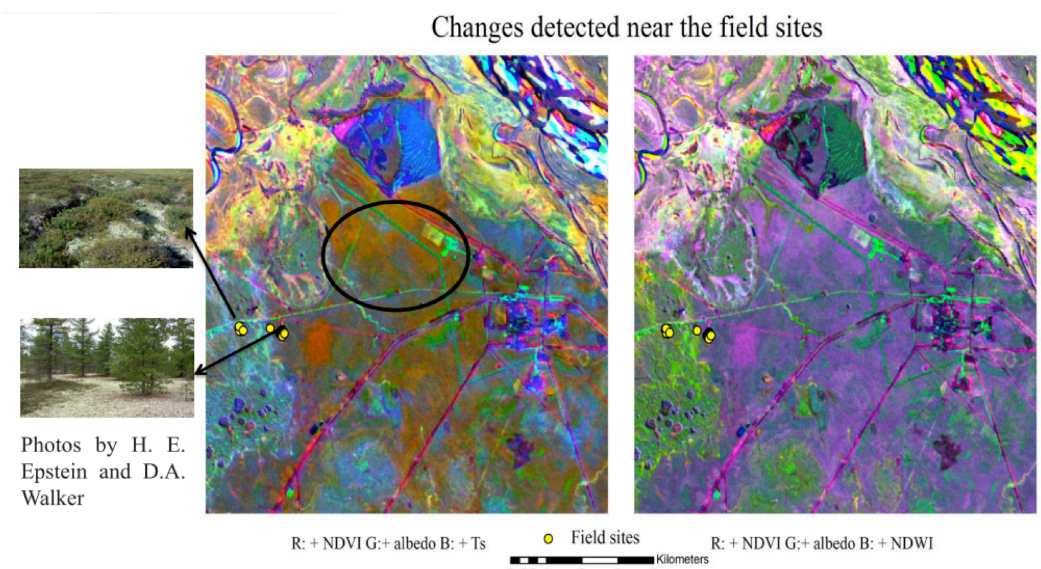

Figure 8. *Composite image of difference map based on derived NDVI, albedo, surface temperature and NDWI between year 2007 and 1988.*

At Nadym, we derived difference maps of NDVI, albedo, surface temperature, NDVI for years 2007 and 1988 (Fig. 8). Expanded gas facilities and new roads are detected with increased albedo. Vegetation appears to have recovered to some degree along old roads. More detailed vegetation change analysis will be based on the higher resolution image analysis.

4.2.3.3 Shrub growth-ring changes in the Yamal region (Bruce Forbes)

Another part of the land-cover-change analysis examined the correspondence between the growth rings of shrub willows and the summer air temperatures in the vicinity of the Yamal Peninsula (Forbes et al. 2010). Annual ring growth of an abundant and nearly circumpolar erect willow (*Salix lanata* L.) from the coastal zone of the northwest Russian Arctic (Nenets Autonomous Okrug) was correlated with station climate data from numerous sites in northwestern Siberia and Europe. The resulting chronology is strongly related to summer temperature for the period 1942–2005. Remarkably high correlations occur at long distances (1600 km) across the tundra and taiga zones of West Siberia and Eastern Europe. There is a clear relationship with photosynthetic activity for upland vegetation at a regional scale for the period 1981–2005, confirming a parallel greening trend reported for similarly warming North American portions of the tundra biome. The standardized growth curve suggests a significant increase in shrub willow growth over the last six decades. These findings are in line with field and remote sensing studies that have assigned a strong shrub component to the reported greening signal since the early 1980s. Furthermore, the growth trend agrees with qualitative observations by nomadic Nenets reindeer herders of recent increases in willow size in the region. The quality of the chronology as a climate proxy is exceptional. Given its wide geographic distribution and the ready preservation of wood in permafrost, *S. lanata* L. has great potential for extended temperature reconstructions in remote areas across the Arctic.

4.2.3.4 Vegetation change at the forest-tundra ecotone, Kharp and other Russia sites (JJ Frost)

We also examined recent vegetation dynamics in forest-tundra ecotones across the Russian Arctic using imagery from the 1960s-era Corona high-resolution satellite missions (Frost et al. 2012, 2013). Corona images were co-registered with recent images and analyzed for changes in the extent and abundance of trees and tall shrubs. Dramatic changes in vegetation cover were evident at several sites over a ~40 year period, including two sites near the southern Yamal. On the Tazovskiy Peninsula, erosion of sandy marine deposits from shallow hillslopes had exposed clayey soils that are nutrient-rich and support highly-productive shrub vegetation (Fig. 9). The surficial geology and disturbance regime of the Tazovskiy site appears to be similar to that of the Vaskiny Dachi field site on the central Yamal, but Tazovskiy is in bioclimate subzone E and alder is a dominant shrub on landslide-affected slopes.

The other site was in the foothills of the Polar Urals near the town of Kharp. We visited Kharp in summers of 2009, 2010, 2011, and 2012 and discovered that an old (~100 YBP), high-intensity fire probably initiated the rapid alder shrub advancement in the area. We observed that alders have established most readily on mineral soils that were exposed either by fire, or by cryogenic processes associated with small patterned-ground features (frost boils, non-sorted circles). Cryogenic disturbance is thought to lead to regularly-spaced “shrub savannas” that are common in the Low Arctic, and which up until now have not been fully explained. The fire/frost-boil/shrub savanna hypothesis is being examined in more detail by Frost as part of his Ph.D. thesis research along the Dalton Highway in Alaska, where there are extensive areas that were burned in 2007-2008, as well as at the Kharp site.

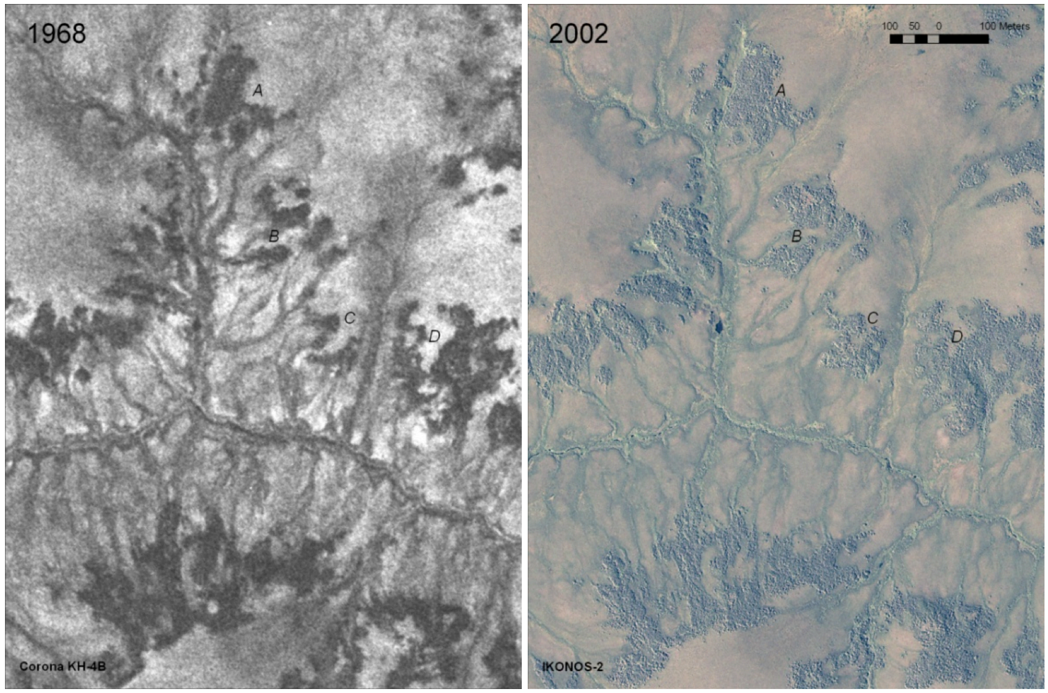

Figure 9. *Remote sensing images of the Tazovskiy Peninsula study site, ~60 km east of the southern Yamal. (Left) 1968 Corona image showing extent of alder shrublands on shallow hillslopes(most dark areas in the image). (Right) Co-registered 2002IKONOS-2 image showing infilling of alders, for examples note the areas in the vicinity of the letters A, B, C, and D.*

4.2.3.5 Landsat NDVI change at Toolik Lake, AK (Martha Raynolds)

NDVI calculated from coarse-resolution sensors has shown strong increases since the 1980s on Alaska's North Slope. We used a time series of Landsat data spanning 22 years (1985-2007) to see if the strongly positive change in NDVI observed with AVHRR data in northern Alaska is also observable at the local scale in an 823 km^2 area near Toolik Lake, AK (Fig. 10) (Raynolds et al. 2013). The rather homogeneous greening documented across northern Alaska at coarser scales (Jia et al. 2003) proved to be very heterogeneous at 30-m pixel resolution, with a strong influence due to glacial history. Small scattered patches of pixels with significant increases in NDVI occurred throughout the younger, late-Pleistocene-age glacial deposits. On older, mid-Pleistocene deposits, increases occurred in few, larger patches of mostly erect dwarf-shrub, sedge tussock tundra, possibly a result of release of nutrients from thawing of ice-rich permafrost. Only 5 % of pixels had significant linear increases in NDVI from 1985-2007 ($n = 6$, $p < 0.05$), while 0.4% showed significant decreases, in small patches whose causes were evident when sampled on the ground. Trends in NDVI varied by glacial history, elevation, slope, and the resulting vegetation conditions. This heterogeneity in response to climate change can be expected throughout much of the Arctic, where complex glacial histories determine existing soil and vegetation characteristics.

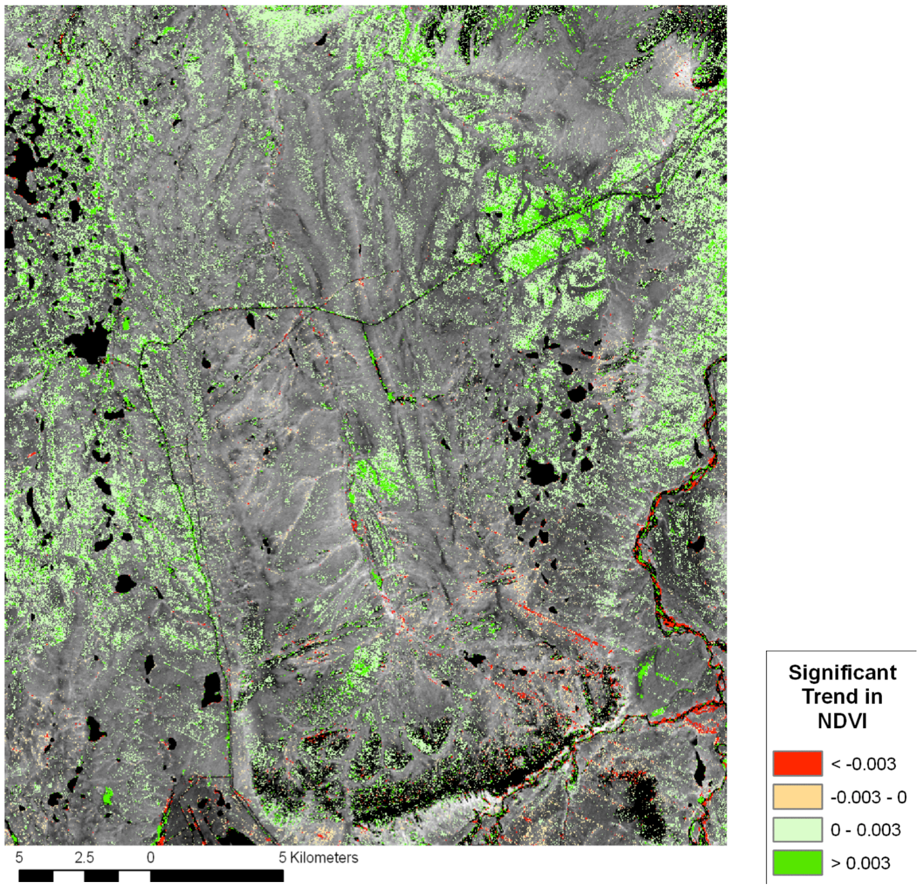

Figure 10. *Areas of significant NDVI change within the Toolik Lake Field Station region, AK (1985-2007). Most o the change has occurred on younger glacial surfaces, and in areas of disturbance, including areas with massive ground ice. (Raynolds et al. 2013).*

4.3 Modeling tundra vegetation change (Howie Epstein, Jed Kaplan, Qin Yu,)

We used the ArcVeg arctic tundra vegetation dynamics model (Epstein et al. 2000) to simulate the combined effects of temperature increases and different grazing regimes on the tundra vegetation biomass, productivity, and species composition. In a recently published paper, we simulated seven sites on the Yamal Peninsula that differ in their soil organic nitrogen (SON) quantities and that are found across three different bioclimate subzones (Fig. 11) (Yu et al. 2009). A 2°C increase in temperature led to aboveground biomass increases ranging from ~150 g m^{-2} to 665 g m^{-2} depending on the subzonal climate and the SON. Increased grazing frequency from every 10 years to every 2 years, reduced the effects of climate change on tundra vegetation, yielding aboveground biomass increases ranging from ~100 g m^{-2} to ~370 g m^{-2}.

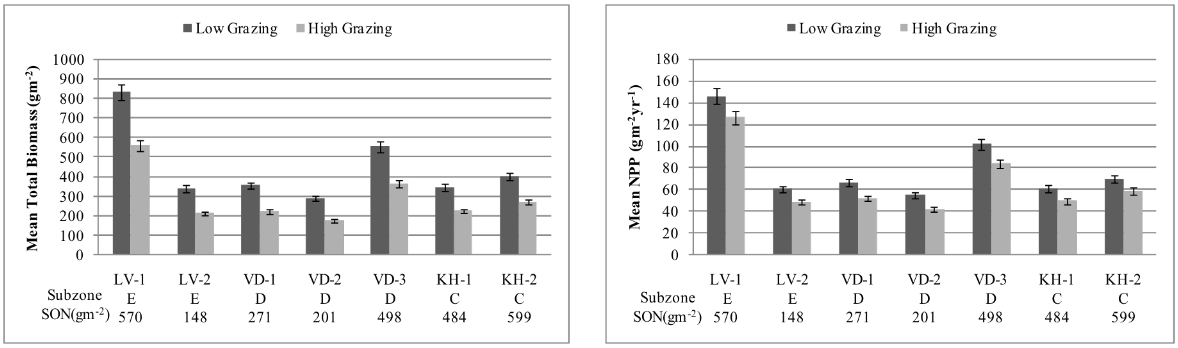

***Fig. 11**. Comparison of tundra biomass and net primary production (NPP) to low and high grazing regimes in three tundra subzones and different levels of soil organic nitrogen (SON). LV-1 = subzone E, loamy soil; LV-2 = subzone E, sandy soil; VD-1 = subzone D, loamy soil; VD-2, subzone D, mixed loamy and sandy soil; VD-3, subzone D, sandy soil; KH-1, subzone C, loamy soil; KH-2, subzone C, mixed loamy and sandy soil.*

We have more recently used the ArcVeg model to examine in more detail the plant functional type (PFT) compositional changes in response to warming and altered grazing regimes on the Yamal Peninsula. We modified the ArcVeg model so that it was parameterized with available reindeer diet data, and grazing in the model is now a function of both foliar nitrogen concentration and plant type preferences. We simulated 11 sites on the Yamal Peninsula (subzones C-E), Belyy Ostrov (subzone B) and Hayes Island (subzone A) across a variety of SON quantities. A total of 132 simulation runs (variations of the 11 sites, three warming scenarios, and four grazing regimes) were analyzed using non-metric multi-scaling (NMS) ordination, and the results indicated that grazing can be as important as latitudinal climate gradient for controlling tundra community structure (Fig. 12).

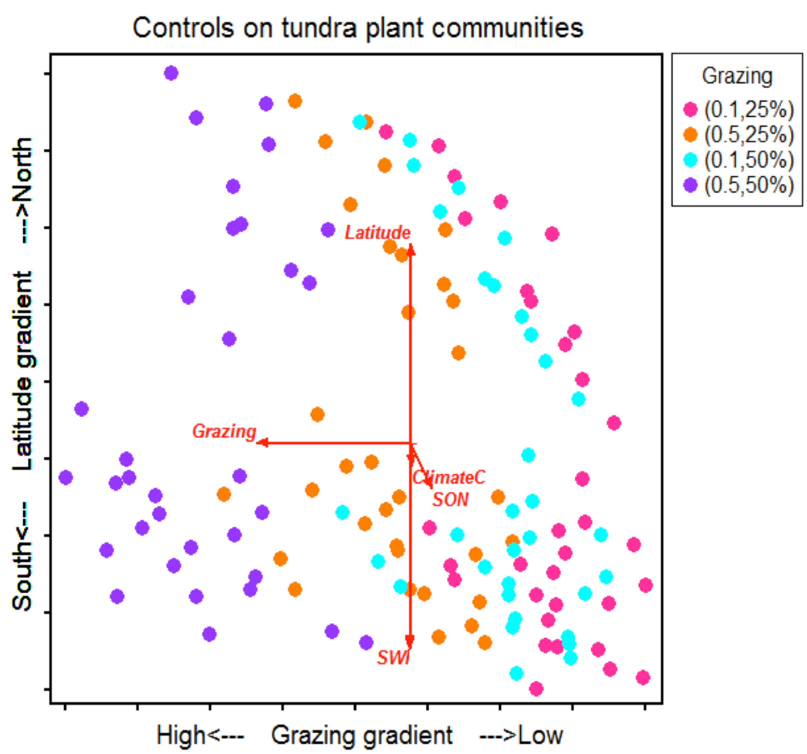

***Figure 12.** Non-metric Multidimensional Scaling (NMS) ordination of effects of different grazing frequency and intensity (in parentheses in legend) along a along the Arctic climate gradient.*

Most PFTs responded to a 2°C increase in temperature with increased biomass with a few exceptions: rushes in the High Arctic (-2%), non-vascular plants (-5%) and dwarf prostrate shrubs (-20~-10%) in the Low Arctic. (Increasing grazing frequency from every 10 years to every 2 years had a greater impact on PFT biomass than changing the annual percentage eaten from 25% to 50%, and most PFT biomass declined in response to increasing grazing intensities except for evergreen shrubs and mosses
(Yu et al. 2011).

In addition to work specific to the Yamal, we are also in the process of conducting circumpolar simulations of tundra vegetation change, using circumpolar maps of tundra subzones, soils, grazing herds, and general circulation model (GCM) output. Jed Kaplan has recently developed a module for his BIOME4 model that simulates the temporal dynamics of soil temperatures and the active layer, which we hope to link with ArcVeg (Kaplan et al. 2010). Finally, we have begun the process of developing a daily version of the ArcVeg model to simulate the effects of changing seasonality on tundra vegetation and carbon cycling. The daily version will include a daily weather generator for climates in all five subzones of both North America and Eurasia, a daily module for the mineralization of nitrogen and the growth of competing plants, empirical equations for the starts and ends of growing seasons, and seasonality of plant functional type activity as well as grazer activity.

4.4 Cumulative effects of resource development and climate change.

4.4.1 Yamal cumulative effects studies (Bruce Forbes, Timo Kupula, Florian Stammler)

The largest land-use changes on the Yamal are related to expanding oil and gas development and changing reindeer-herding practices (Forbes et al. 2009). The Yamal region has 200 identified natural gas fields containing an estimated 58 trillion m3 of gas reserves and is poised for widespread development of industrial infrastructure and concomitant growth of urban centers and human population (Gubarkov 2010, Kumpula et al. 2012). So far, most industrial infrastructure is concentrated in a 450-km2 area of the super-giant Bovanenkovo gas field on the central Yamal. Development of other gas fields is now accelerating following the completion in 2011 of a railway linking Bovanenkovo to the rest of Russia (Gubarkov 2010, Kumpula et al. 2012). Amidst the backdrop of rapid industrial development, changing climate and altered ecosystems, about 6,000 indigenous Nenets people and their 310,000 domestic reindeer migrate annually across the Yamal (Stammler 2005). The seasonal movements of the Nenets and their reindeer are directly impacted by the spread of pipelines, roads, and other infrastructure, and the rapidly expanding herds have their own effects on the landscape through extensive grazing and trampling (Forbes et al. 2009, Kumpula et al. 2012). Thus, the Nenets' ability to sustain their traditional land-use practices is challenged by complex socio economic and environmental factors and uncertainties about future climate change, industrial development, and regional population growth.

The Yamal peninsula encompasses a tightly integrated arctic social-ecological system (SESs) (Forbes et al. 2009). In contrast to northern Alaska and Canada, most terrestrial and aquatic components of West Siberian oil and gas fields are seasonally exploited by migratory herders, hunters, fishers, and domesticated reindeer (*Rangifer tarandus* L.). Despite anthropogenic fragmentation and transformation of a large proportion of the environment, recent socioeconomic upheaval, and pronounced climate warming, the team found the Yamal Nenets SES highly resilient according to a few key measures. The system has successfully reorganized to a remarkable extent to recent shocks. However, expansion of infrastructure, concomitant terrestrial and freshwater ecosystem degradation, climate change, and a massive influx of workers underway present a looming threat to future resilience.

4.4.2 Prudhoe Bay cumulative effects studies (Martha Raynolds, Skip Walker, Gary Kofinas)

New industrial developments are expected to proliferate as Arctic sea ice melts and natural resources become more accessible. Most of the existing and future developments will be in areas of ice-rich permafrost that pose significant hazards to these developments. We recently began a study of the cumulative effects of development and climate change in the ice-rich permafrost landscapes in northern Alaska. We documented 62 years (1949-2011) of change in the Prudhoe Bay Oilfield (PBO) region, the oldest and most extensive major industrial complex in the Arctic (Walker et al. 2012c, Raynolds et al. 2013, 2012a). We mapped the historical changes in infrastructure for all the North Slope oilfields for 10 dates from the initial oil discovery in 1968 to 2011. We also mapped at finer scale the baseline geoecological conditions prior to development, historical anthropogenic changes, and natural changes within three 22-km^2 intensively developed portions of the PBO. The industrial footprint grew rapidly during the early years after discovery and leveled off after 20 years, covering 74 km^2 by 2011, whereas, indirect effects continued to expand after the main construction phase ended (Fig. 13a). By 2010, over 40% of the intensively mapped area was affected by oil development. Between 1990 and 2001, coincident with strong atmospheric warming during the 1990s, 17.7% of the natural landscapes developed new thermokarst features and more rapid lake-shore erosion resulting from thawing of ice-wedges (Fig. 13b). The increased landscape heterogeneity with abundant small ponds and greater microrelief may foretell a transition to new permafrost and hydrology states and have major implications for construction costs, carbon budgets, tundra organisms and ecosystem services. Documenting the changes associated with development can inform adaptive management approaches to minimize the impacts of future activities.

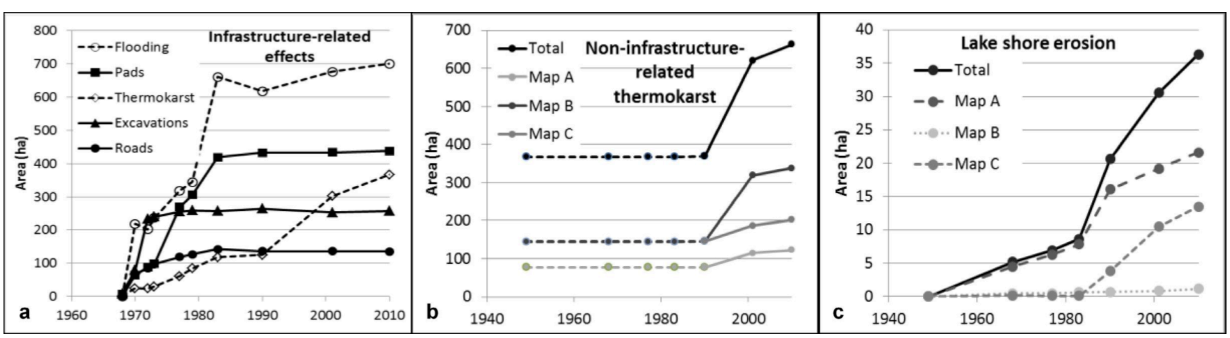

Figure 12. *History of changes (1949-2010) in three 22-km^2 mapped areas within Prudhoe Bay Oilfield, North Slope, Alaska:* ***a.*** *History of infrastructure-related effects – direct effects (solid lines) and indirect effects (dashed lines);* ***b.*** *history of four common non-infrastructure-related changes;* ***c.*** *history of lake-shore erosion for Maps A, B and C and for the total mapped area (66 km^2). Both infrastructure-related and non-infrastructure-related thermokarst and lake shore erosion show major transitions starting in 1990 toward greater levels of erosion and permafrost degradation that correspond with a series of unusually warm summers. (From Raynolds et al. 2013, submitted.)*

5 Publications (includes publications from the first round of funding)

5.1 Published papers and book chapters

2013

Epstein, H. E., I. Myers-Smith, and D. A. Walker. 2013. Recent dynamics of arctic and sub-arctic vegetation. Environmental Research Letters 8:015040.

Frost, G. V., H. E. Epstein, D. A. Walker, G. Matyshak, and K. Ermokhina. 2013. Patterned-ground facilitates shrub expansion in Low Arctic tundra. Environmental Research Letters 8:015035.

Frost, G. V., H. E. Epstein, D. A. Walker, G. V. Matyshak, and K. A. Ermokhina.. 2013. The 2011 Expedition to Kharp, Southern Yamal Peninsula Region, Russia. Alaska Geobotany Center Data Report, University of Alaksa, Fairbanks, Fairbanks, AK:1–72.

Parmentier, F. J., T. R. Christensen, L. L. Sørensen, S. Rysgaard, A. D. McGuire, P. A. Miller, and D. A. Walker. 2013. The Impact of a Lower Sea Ice Extent on Arctic Greenhouse Gas Exchange. Nature Climate Change 3:195–202.

Post, E., U. Bhatt, C. Bitz, J. Brodie, T. L. Fulton, M. Hebblewhite, J. Kerby, S. Kutz, I. Stirling, and D. A. Walker. 2013 in press. Ecological consequences of sea ice decline. Science.

Raynolds, M. K., D. A. Walker, D. Verbyla, and C. A. Munger. 2013. Patterns of Change within a Tundra Landscape: 22-year Landsat NDVI Trends in an Area of the Northern Foothills of the Brooks Range, Alaska. Arctic, Antarctic, and Alpine Research 45:249–260.

Raynolds, M. K., D. A. Walker, K. Ambrosius, J. Brown, K. R. Everett, M. Kanevskiy, G. P. Kofinas, V. R. Romanovsky, Y. Shur, and P. J. Webber. 2013. Cumulative landscape effects of six decades of infrastructure- and climate-related changes in the Prudhoe Bay Oilfield, Alaska. 2013 submitted, Proceedings of the National Academy of Science.

Walker, D. A., T. D. Hamilton, C. Munger, and H. A. Maier. 2013 in press. Glacial history and long-term ecology in the Toolik Lake region. *in* J. Hobbie and G. Kling, editors. A changing Arctic: Ecological consequence for tundra, streams and lakes. Oxford University Press, Oxford.

Ims, R., D. Ehrich, D.A. Walker et al. 2013 in press. Arctic terrestrial ecosystems. Chapter 12. *Arctic Biodiversity Assessment*. Conservatation of Arctic Flora and Fauna, Akureyri, Iceland.

Walker, D. A., I. G. Alsos, C. Bay, N. Boulanger-Lapointe, A. L. Breen, H. Bültmann, T. Christiansen, C. Damgaard, F. J. A. Daniels, S. M. Hennekens, P. C. Le Roux, M. Luoto, L. Pellisier, R. K. Peet, N. M. Schmidt, L. Stewart, N. G. Yoccoz, and M. S. Wisz. 2013. Rescuing valuable Arctic vegetation data for biodiversity models, ecosystem models and a panarctic vegetation classification. Arctic:133–137.

2012

Bieniek, P.A., 2012: *Assessing River Ice Breakup Date, Coastal Tundra Vegetation and Climate Divisions in the Context of Alaska Climate Variability*, Ph.D. thesis University of Alaska, pdf. Available on-line at: http://ffden-2.phys.uaf.edu/atm/atm/graduates.html_files/Bieniek_P_PhD2012Thesis.pdf

Bieniek P., U. Bhatt, D. Walker, M. Raynolds, J. Comiso, H. Epstein, J. Pinzon, C. Tucker, R. Thoman, H. Trang, N. Mölders, W. Ermold, J. Zhang, and M. Steele, 2012: Alaska coastal tundra vegetation links to climate. *Earth Interactions*, in preparation for submission.

Bhatt et al. 'Drivers of Recent Pan-Arctic Tundra Vegetation Variability and Change' *Earth Interactions*, in preparation for submission.

Epstein, H. E., D. A. Walker, U. S. Bhatt, P. Bieniek, J. Comiso, J. Pinzon, M. K. Raynolds, C. J.
Tucker, G. J. Jia, H. Zeng, I. H. Myers-Smith, B. C. Forbes, D. Blok, M. M. Loranty, P. S. A.
Beck, S. J. Goetz, T. V. Callaghan, G. H. R. Henry, C. E. Tweedie, P. J. Webber, A. V.
Rocha, G. R. Shaver, and J. M. Welker. (2012a). Vegetation: Arctic Report Card: Update for
2012.

Epstein, H. E., M. K. Raynolds, D. A. Walker, U. S. Bhatt, C. J. Tucker, and J. E. Pinzon. 2012.
Dynamics of aboveground phytomass of the circumpolar Arctic tundra during the past three decades. Environmental Research Letters 7:015506.

Fauria, M.M., Forbes, B.C., Zetterberg, P., Kumpula, T. 2012. Eurasian Arctic greening reveals teleconnections and the potential for novel ecosystems. *Nature Climate Change*. . doi: 10.1038/nclimate1558.

Kumpula, T., Forbes, B.C., Stammler, F., Meschtyb, N. 2012. Dynamics of a Coupled System: Multi-Resolution Remote Sensing in Assessing Social-Ecological Responses during 25 Years of Gas Field Development in Arctic Russia. *Remote Sensing: Human-Induced Global Change*. 4(4):1046-1068. PDF. doi: 10.3390/rs4041046.

Raynolds, M.K., Walker, D.A., Epstein, H.E., Pinzon, J.E., Tucker, C.J. 2012. A new estimate of tundra-biome phytomass from trans-Arctic field data and AVHRR NDVI. *Remote Sensing Letters*. 3:403-411. PDF. doi: 10.1080/01431161.2011.609188.

Raynolds, M. K., D. A. Walker, D. Verbyla, and C. A. Munger. 2013. Patterns of Change within a Tundra Landscape: 22-year Landsat NDVI Trends in an Area of the Northern Foothills of the Brooks Range, Alaska. Arctic, Antarctic, and Alpine Research 45:249–260.

Walker, D.A., U.S. Bhatt, H.E. Epstein, P. Bieniek, J. Comiso, G.V. Frost, J. Pinzon, M.K Raynolds, and C.J. Tucker, 2012a: [The Arctic] *Changing Arctic Tundra Vegetation Biomass and Greenness*— [in "State of the Climate in 2011"]. Bull. Amer. Meteor. Soc., 93 (7), S138-S139

2011

Goetz, S.J., Epstein, H.E., Alcaraz, J.D., et al. 2011. Recent changes in Arctic vegetation: Satellite observations and simulation model predictions. *Eurasian Arctic Land Cover and Land Use in a Changing Climate*. Springer. New York.VI pp. 9-36. PDF

Khitun, O.V., Ermokhina, K.A., Leibman, M.O., Khomutov, A.V. 2011. Plant species indicating the depth of active layer on the Bely Island. *Fourth Russian Conference on Geocryology, Moscow, Russia, June 7-9*.

Leibman, M.O., Moskalenko, N.G., Orekov, P.T., et al. 2011. Interaction of cryogenic and biotic components in cryolithozone of the West Siberia along the Yamal transect. *Polar cryosphere and hydrosphere of the Land*. 3.

Walker, D.A., Forbes, B.C., Leibman, M.O., et al. 2011. Cumulative effects of rapid land-cover and land-use changes on the Yamal Peninsula, Russia. *Eurasian Arctic Land Cover and Land Use in a Changing Climate*. Springer. New York.VI pp. 206-236. PDF

2010

Alcaraz, J.D., Cabello, J., Epstein, H.E., Jia, G.J. 2010. Trends in the surface vegetation dynamics of the tundra and taiga network of protected areas in Eurasia as observed by satellite sensors. *in prep.*.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Role of atmospheric processes in trends and variability of sea-ice, land-surface temperatures, and tundra vegetation greenness in Alaska. *submitted to Atmospheric Research*.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Circumpolar Arctic tundra vegetation change is linked to sea-ice decline. *Earth Interactions*. 14:(8):1-20. PDF

Epstein, H.E., Walker, D.A., Raynolds, M.K., et al. 2010. Vegetation and soil attributes along two latitudinal temperature gradients in arctic tundra. *submitted to Ecology*.

Forbes, B.C., Fauria, M.M., Zetterberg, P. 2010. Russian Arctic warming and 'greening' are closely tracked by tundra shrub willows. *Global Change Biology*. 16:1542-1554. PDF

Forbes, B.C., Fauria, M.M., Zetterberg, P., Kumpula, T. 2010. Deciduous shrub growth and the greening of the Arctic in West Siberia. Abstract GC53B-08, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

Forbes BC, Stammler F. 2009. Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia. *Polar Research* 28: 28–42.

Frost, G.V., Epstein, H.E., Walker, D.A., et al. 2010. Spatio-temporal trends in vegetation structure and NDVI in Low Arctic northwest Siberia: evidence from the satellite record and ground observations. Abstract GC54A-03, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

Gould, W.A., Gonzalez, G., Walker, D.A., Ping, C.L. 2010. Commentary. Integrating research, education, and traditional knowledge in ecology: a case study of biocomplexity in Arctic ecosystems. *Arctic, Antarctic and Alpine Research*. 42:(4):379-384. PDF

Gubarkov, A.A., Leibman, M.O. 2010. Bead-shaped channel forms as an evidence of paragenesis of cryogenic and hydrological processes in the small-river valleys of Central Yamal. *Earth Cryosphere*. 14:(1):41-49.

Kumpula, T., Forbes, B.C., Stammler, F. 2010. Remote sensing and local knowledge of hydrocarbon exploitation: the case of Bovanenkovo, Yamal Peninsula, West Siberia, Russia. *Arctic*. 63:(2):165-178.

Kumpula, T., A. Pajunen, E.M. Kaarlejärvi, B.C. Forbes, and F. Stammler (2011). Land use and land cover change in arctic Russia: ecological and social implications of a state shift from shrub- to graminoid-dominated tundra. *Global Environmental Change* doi:10.1016/j.gloenvcha.2010.12.010.

Pinzon, J.E., Raynolds, M.K., Pak, E.W., et al. 2010. NDVI3g: a consistent long term vegetation index data set optimized for polar trend analysis. *Geoscience and Remote Sensing Letters*.

Raynolds, M.K., Huettmann, F., Walker, D.A., Verbyla, D. 2010. Environmental controls of the distribution of circum-Arctic vegetation. *Ecography*.

Raynolds, M.K., Walker, D.A., Verbyla, D., Munger, C.A. 2010. Changes in tundra vegetation over 25 years as measured by Landsat NDVI in the Upper Kuparuk River Basin, North Slope Alaska, 1985-2009. Abstract GC43B-0984, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

Talbot, S.S., Walker, D.A. 2010. Circumboreal Vegetation Mapping (CBVM) Project: Introduction and objectives. *Proceedings of the Fifth International Workshop: Conservation of Arctic Flora and Fauna (CAFF) Flora Group*. International Secretariat, CAFF Flora Expert Group (CFG). Helsinki, Finland. pp..

Walker, D.A. 2010. A Vegetation map of arctic tundra and boreal forest regions: Integrating the CAVM with the Circumboreal Vegetation Map. *Proceedings of the Fifth International Workshop: Conservation of Arctic Flora and Fauna (CAFF) Flora Group*. International Secretariat, CAFF Flora Expert Group (CFG). Helsinki, Finland. pp..

Walker, D.A. 2010. Greening of the Arctic: Spatial and temporal (1982-2009) variation of circumpolar tundra NDVI and aboveground biomass. Abstract GC53B-01, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

Walker, D.A., Bhatt, U.S., Comiso, J.C., et al. 2010. e. Land l) Vegetation. *Special Supplement to Bulletin of the American Meteorological Society*. 91:S115-S116.

Walker, D.A., Epstein, H.E., Frost, G.V., Raynolds, M.K. 2010. Vegetation and environmental factors along a 900-km Arctic bioclimate transect on the Yamal Peninsula, Russia. *submitted to Journal of Applied Vegetation Science*.

Walker, D.A., Epstein, H.E., Kade, A.N., et al. 2010. Vegetation of zonal patterned-ground ecosystems along the North America Arctic Transect. *Applied Vegetation Science*.

Yu, Q., Epstein, H.E., Walker, D.A., Frost, G.V. 2010. Modeling dynamics of tundra plant communities on the Yamal Peninsula. Abstract GC54A-04, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

2009

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2009. Seasonality of the air-sea-ice-land environment of Arctic tundra in Northern Eurasia and North America. Abstract GC31A-0701, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0701. PDF

Epstein, H.E., Walker, D.A., Raynolds, M.K., et al. 2009. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. Abstract GC31A-0697, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0697. PDF

Forbes, B.C., Stammler, F., Kumpula, T., et al. 2009. High resilience in the Yamal-Nenets social-ecological system, west Siberian Arctic, Russia. *Proc. Natl. Acad. Sci.*. 106:22041-22048. PDF

Frost, G.V., Epstein, H.E., Walker, D.A. 2009. Spatio-temporal trends in tree and tall shrub cover in the Eurasian Low Arctic: evidence from 1960s and contemporary satellite imagery and ground observations. Abstract GC31A-0698, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0698. PDF

Groisman, P.Y., Clark, E.A., Kattsov, V.M., et al. 2009. The Northern Eurasia Earth Science Partnership: An example of Science Applied to Societal Needs. *Bulletin of the American Meteorological Society*. 90:671-688. PDF

Jennings, M.D., Faber-Langendoen, D., Loucks, O.L., et al. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. *Ecological Monographs*. 79:173-199.

Jia, G.J., Epstein, H.E., Walker, D.A. 2009. Vegetation greening in the Canadian Arctic related to decadal warming. *Journal of Environmental Monitoring*. 11:2231-2238.

Kataoka, M. 2009. ESRI Map Book, Volume 24. *ESRI Map Book*. 24:(24):120. PDF

Kelley, A.M., Epstein, H.E. 2009. Effects of nitrogen fertilization on plant communities of nonsorted circles in moist nonacidic tundra, Northern Alaska. *Arctic, Antarctic, and Alpine Research*. 41:(1):119-127. PDF

Khomutov, A.V., Leibman, M.O., Moskalenko, N.G., et al. 2009. Numerical characteristics of vegetation and their influence on active layer depth. *International Workshop on the results of IPY, Sochi, Krasnodar Krai, Russia, 28 September - 1 October*. 81-82.

Leibman, M.O., Khomutov, A.V. 2009. Environmental controls of the thaw depth and rate of thaw under climate fluctuations. *Association of American Geographers Annual Meeting, Las Vegas, NV, March 22-27*. PDF

Leibman, M.O., Ukraintseva, N.K. 2009. Mechanisms and geoecological consequences of cryogenic landslides in the area of marine sedimentation. Abstract EGU2009-3980, presented at *European Geosciences Union General Assembly 2009, Vienna, Austria, April 19-24*. 11:EGU2009-3980.

Raynolds, M.K., Walker, D.A. 2009. Effects of deglaciation on circumpolar distribution of arctic vegetation. *Canadian Journal of Remote Sensing*. 35:(2):118-129. PDF

Sappington, N. 2009. ESRI Map Book, Volume 20. *ESRI Map Book*. 20:(20):120. PDF

Walker, D.A., Bhatt, U.S., Epstein, H.E., et al. 2009. Circumpolar Arctic greening: Relationships to summer sea-ice concentrations, land temperatures and disturbance regimes. Abstract GC43B-08, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC43B-08. PDF

Walker, D.A., Bhatt, U.S., Epstein, H.E., et al. 2009. Circumpolar Arctic greening: Relationships to summer sea-ice concentrations, land temperatures and disturbance regimes. Abstract GC43B-08, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC43B-08. PDF

Walker, D.A., Bhatt, U.S., Raynolds, M.K., et al. 2009. Vegetation. *Arctic Report Card 2008*. 3. PDF

Walker, D.A., Bhatt, U.S., Raynolds, M.K., et al. 2009. The Arctic: Land: Vegetation. *State of the Climate in 2008*. 90 pp. S104-S105.

Walker, D.A., Hamilton, T.D., Ping, C.-L., et al. 2009. Dalton Highway Field Trip Guide for the Ninth International Conference on Permafrost. *Division of Geological and Geophysical Surveys. Fairbanks, AK. 9: pp: 117*. PDF

Walker, D.A., Leibman, M.O., Epstein, H.E., et al. 2009. Spatial and temporal patterns of greenness on the Yamal Peninsula, Russia: interactions of ecological and social factors affecting the Arctic normalized difference vegetation index. *Environmental Research Letters*. 4:16. PDF

Walker, D.A., Raynolds, M.K., Maier, H.A., et al. 2009. Circumpolar geobotanical mapping: a web-based plant-to-planet approach for vegetation-change analysis in the Arctic. *Mapping and Monitoring of Nordic Vegetation and Landscapes, Hverager ði, Iceland, 16-18 September*. 4. PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2009. Simulating soil organic nitrogen and grazing effects on arctic vegetation dynamics on the Yamal Peninsula, Russia. *Environmental Research Letters*. 4:(4). PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2009. Simulating soil organic nitrogen and grazing effects on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia. Abstract GC31A-0693, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0693.

2008

Bhatt, U.S., Walker, D.A., Raynolds, M., Comiso, J. 2008. Examining relationships between sea ice and Arctic vegetation on the Pan-Arctic, regional and site scales. Abstract EGU2008-A-11271, presented at *European Geosciences Union General Assembly 2008, Vienna, Austria, 13 -18 April*. 10:EGU2008-A-11271.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2008. Application of Space-based Technologies and Models to Address Land-cover/Land-use Change Problems on the Yamal Peninsula, Russia: Circumpolar and regional analysis of the relationship between sea-ice variability, summer land-surface temperatures, Arctic t. *NASA Carbon Cycle and Ecosystems Joint Science Workshop, Adelphi, MD, April 28 - May 2*. PDF

Brown, J., Romanovsky, V.E. 2008. Report from the International Permafrost Association: State of Permafrost in the First Decade of the 21st Century, Permafrost and Periglacial Processes. *Permafrost and Periglacial Processes*. 19:(2):255-260.

Comiso, J.C., Nishio, F. 2008. Trends in the sea ice cover using enhanced and compatible AMSR-E,SSM/I, and SMMR data. *Journal of Geophysical Research*. 113:C02S07. PDF

Comiso, J.C., Parkinson, C.L., Gersten, R., Stock, L. 2008. Accelerated decline in the Arctic sea ice cover. *Geophysical Research Letters*. 35:L01703. PDF

Cook, B., Bonan, G., Levis, S., Epstein, H. 2008. Rapid vegetation responses and feedbacks amplify climate model response to snow cover changes. *Climate Dynamics*. 30:(4):391-406. PDF

Cook, B.I., Bonan, G.B., Levis, S., Epstein, H.E. 2008. The thermoinsulation effect of snow cover within a climate model. *Climate Dynamics*. 31:(1):107-124. PDF

Epstein, H.E., Walker, D.A., Kuss, P., Karlejaärvi, E. 2008. Tundra vegetation properties along a latitudinal gradient of the Yamal Region of Russia. *NASA Carbon Cycle and Ecosystems Joint Science Workshop, Adelphi, MD, April 28 - May 2*.

Epstein, H.E., Walker, D.A., Kuss, P., et al. 2008. Ecosystem Properties along a Latitudinal Gradient of the Yamal Region, Russia. Abstract EGU2008-A-04406, presented at *European Geosciences Union General Assembly, Vienna, Austria, 13 - 18 April*. 10:EGU2008-A-04406. PDF

Forbes, B.C. 2008. Equity, vulnerability and resilience in social-ecological systems: a contemporary example from the Russian Arctic. *Research in Social Problems and Public Policy*. 15:203-236.

Gubarkov, A.A., Leibman, M.O. 2008. Interrelation of Cryogenic and Hydrologic Processes on Small Streams and Catchments of Central Yamal. *Ninth International Conference on Permafrost, Fairbanks, AK, June 29 - July 3*.

Gubarkov, A.A., Leibman, M.O. 2008. Influence of cryogenic landforms on the types of runoff within the Central Yamal river basins (VaskinyDachi research polygon). *Cryogenic resources of the Polar and Mountainous regions: State and prospects of engineering geocryology, Tyumen, Russia, April 21-24*.

Jia, G.J., Epstein, H.E., Walker, D.A., Wang, H. 2008. Decadal changes of phenological patterns over arctic tundra biome. Abstract C21C-0559, presented at *AGU Fall Meeting, San Francisco, CA, Dec. 15-19*. 89:C21C-0559. PDF

Leibman, M.O., Epstein, H.E., Khomutov, A.V., et al. 2008. Relation of active layer depth to vegetation on the central Yamal Peninsula, Russia. *Ninth International Conference on Permafrost, Fairbanks, AK, June 29-July 3*. Extended Abstracts:177-178. PDF

Raynolds, M.K., Comiso, J.C., Walker, D.A., Verbyla, D. 2008. Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. *Remote Sensing of Environment*. 112:(4):1884-1894. PDF

Raynolds, M.K., Walker, D.A. 2008. Circumpolar relationships between permafrost characteristics, NDVI, and arctic vegetation types. *Ninth International Conference on Permafrost, Fairbanks, AK, June 29-July 3*. 2:1469-1474. PDF

Romanovsky, V.E., Kholodov, A.L., Marchenko, S.S., et al. 2008. Thermal state and fate of permafrost in Russia: First results of IPY. *Ninth International Conference on Permafrost, Fairbanks, AK, June 28-July3*. 2:1511-1518. PDF

Vasiliev, A.A., Leibman, M.O., Moskalenko, N.G. 2008. Active Layer Monitoring in West Siberia under the CALM II Program // Permafrost. *Ninth International Conference on Permafrost, Fairbanks, AK, June 29-July 3*. 2:1815-1820.

Walker, D.A., Bhatt, U.S., Epstein, H.E. 2008. Greening of the Arctic: an IPY Initiative. Abstract U23F-05 INVITED, presented at *AGU Fall Meeting, San Francisco, CA, December 12-15*. 89:1. PDF

Walker, D.A., Bhatt, U.S., Romanovsky, V.E., et al. 2008. Application of space-based technologies and models to address land-cover/land-use change problems on the Yamal Peninsula, Russia. Abstract EGU2008-A-05697, presented at *European Geosciences Union General Assembly 2008, Vienna, Austria, April 13-18*. 10:EGU2008-A-05697. PDF

Walker, D.A., Leibman, M.O., Forbes, B.C., Epstein, H.E. 2008. Cumulative effects of rapid climate and land-use changes on the Yamal Peninsula, Russia. Abstract GC52A-07, presented at *AGU Fall Meeting, San Francisco, CA, December 15-19*. 89:GC52A-07. PDF

Yu, Q., Epstein, H.E. 2008. Evaluating Arctic tundra system resilience to grazing disturbances: A modeling approach. Abstract EGU2008-A-12154, presented at *European Geosciences Union General Assembly 2008, Vienna, Austria, 13 - 18 April*. 10:EGU2008-A-12154. PDF

2007

Alcaraz, D., Chuvieco, E., Epstein, H. 2007. Temporal trends in post-fire regeneration patterns of boreal forests using 1km AVHRR NDVI. Abstract B11D-0777, presented at *AGU Fall Meeting, San Francisco, CA, December 10-14*. 88:5.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2007. The relationship between sea ice variability and arctic tundra on the pan-Arctic, regional, and site scales. Abstract U42C-0612, presented at *AGU Fall Meeting, San Francisco, CA, December 10*. 88:5.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2007. Influence of Regional Sea Ice Variability on Arctic Tundra. *Seventh International Conference on Global Change: Connection to the Arctic, Fairbanks, Alaska, February 19-20*. 76-78. PDF

Cook, B.I., Bonan, G.B., Levis, S., Epstein, H.E. 2007. Dynamic vegetation amplifies climate model response to snow cover changes. *Climate Dynamics* .

Epstein, H.E., Yu, Q., Kaplan, J.O., Lischke, H. 2007. Simulating future changes in arctic and subarctic vegetation. *Computing in Science and Engineering*. 9:(4):12-23. PDF

Jia, G.J., Epstein, H.E., Walker, D.A. 2007. Trends of Vegetation Greenness in the Arctic from 1982-2005. Abstract B21A-0041, presented at *AGU Fall Meeting, San Francisco, CA, December 10-14*. 88:5. PDF

Stammler, F., Forbes, B.C. 2007. Declaration on coexistence of oil & gas activities and indigenous communities on Nenets and other territories in the Russian North. *Symposium on Oil and Gas Development in NAO and YNAO, Rovaniemi, Finland, 10-11 December*. PDF

Ukraintseva, N.G., Leibman, M.O. 2007. The effect of cryogenic landslides (active-layer detachments) on fertility of tundra soils on Yamal peninsula, Russia. *1st North American Landslide Conference, Vail, CO, June 3-8*. 1605-1615. PDF

Walker, D.A. 2007. The Circumpolar Arctic Vegetation Map, the Alaska Arctic Tundra Vegetation Map, and the Arctic Geobotanical Atlas. *Proceedings of the Fourth International CAFF Flora Group Workshop, Tórshavn, Faroe Islands, May 5-17*. 60-62. PDF

vanBogaert, R., Walker, D.A., Jia, G.J., et al. 2007. Recent changes in vegetation. *Arctic Report Card 2007*. 8. PDF

2006

Comiso, J.C. 2006. Arctic warming signals from satellite observations. *Weather*. 61:(3):70-76. PDF

Cook, B.I., Bonan, G.B., Levis, S., et al. 2006. Amplification of climate model response to snow cover fraction parameterization through dynamic vegetation. Abstract C21C-1181, presented at *AGU Fall Meeting, San Francisco, CA, December 11-15*. 87:C21C-1181.

Jia, G.J., Epstein, H.E., Walker, D.A. 2006. Spatial heterogeneity of tundra vegetation response to recent temperature changes. *Global Change Biology*. 12:42-55. PDF

Jia, G.J., Epstein, H.E., Walker, D.A. 2006. Decadal changes of vegetation greenness in the Canadian Arctic.Abstract C51A-0383, presented at *AGU Fall Meeting, San Francisco, CA, December 11-15*. 87:C51A-0383.

Kumpula, T., Forbes, B.C., Stammler, F. 2006. Combining data from satellite images and reindeer herders in arctic petroleum development: the case of Yamal, West Siberia. *Nordia Geographical Publications*. 35:(2):17-30. PDF

Raynolds, M.K., Walker, D.A. 2006. Satellite land surface temperatures and tundra vegetation. *Arctic Science Conference, Fairbanks, AK, October 2-4*. 55.

Raynolds, M.K., Walker, D.A., Kade, A.N., et al. 2006. Aboveground Phytomass of Vegetation Communities Along an Arctic Climate Gradient. Abstract C51A-0385, presented at *AGU Fall Meeting, San Francisco, CA, December 11-15*. 87:C51A-0385.

Raynolds, M.K., Walker, D.A., Maier, H.A. 2006. NDVI patterns and phytomass distribution in the circumpolar Arctic. *Remote Sensing of Environment*. 102:271-281. PDF

5.2 Talks (without published abstracts):

2013

Bhatt, U.S. Walker, D.A. Bieniek, P.A. Raynolds, M.K. Epstein, H.E. Comiso, J.C. Pinzon, J. Tucker, C.J. 2013. Links between Pan-Arctic Tundra Vegetation Change and Climate. *Seminar at Geophysical Institute, University of Bergen. Bergen, Norway February 20*. PDF

2012

Epstein, H.E., Raynolds, M.K., Walker, D.A., Bhatt, U.S., Tucker, C.J., Pinzon, J.E., Frost, G.V., Yu, Q., Jia, G.J., Zeng, H. 2012. Recent dynamics of arctic tundra vegetation: Remote sensing, field observations, and modeling. *IPY 2012 From Knowledge to Action. Montreal, Quebec April 22-27*. PDF

Epstein, H.E., Yu, Q., Frost, G.V., Raynolds, M.K., Walker, D.A., Bhatt, U.S., Tucker, C.J., Pinzon, J.E. 2012. Climate and grazing influences on circumpolar dynamics of arctic tundra vegetation. *12th International Circumpolar Remote Sensing Symposium. Levi, Finland May 14-18*. PDF

Ermokhina, K. 2012. Phytoindication of Landslide Disturbances in the Central Yamal. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Forbes, B.C. 2012. Summary of the Finnish contribution to the LCLUC project. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Frost, G.V., Epstein, H.E., Matyshak, G., Ermokhina, K., Walker, D.A. 2012. Summary of Kharp field expedition, July 2011. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A., Matyshak, G., Ermokhina, K. 2012. Feedbacks between shrubland development and permafrost in the northwest Siberian Low Arctic. *12th International Circumpolar Remote Sensing Symposium. Levi, Finland May 14-18*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A., Matyshak, G., Ermokhina, K. 2012. Feedbacks between shrubland development and permafrost in the northwest Siberian Low Arctic. *IPY 2012 From Knowledge to Action. Montreal, Quebec April 22-27*. PDF

Heim, B., Bartsch, A., Buchhorn, M. 2012. I. SATELLITE-BASED PRODUCTS, EVALUATION - II. Up-Scaling, Calibration and Experiments-Yamal. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Heim, B., Bartsch, A., Elger, K., Permafrost Team, E.D. 2012. Circum-Arctic Satellite-Based Service. *12th International Circumpolar Remote Sensing Symposium. Levi, Finland May 14-18*. PDF

Khomutov, A., Leibman, M.O., Moskalenko, N., Orekhov, P., Mullanurov, D. 2012. Database of EAT permafrost information. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Kumpula, T., Forbes, B.C., Stammler, F., Meschtyb, N. 2012. Remote sensing and gis analysis of anthropogenic and natural land use and land cover changes in tundra environments in Bovanenkovo gas field on Yamal Peninsula, Russia.. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Leibman, M.O., Gubarkov, A.A., Khitun, O.V., Khomutov, A.V., Moskalenko, N.G., Orekhov, P.T. 2012. Summary of the Russian contribution to the LCLUC project. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Leibman, M.O., Khitun, O.V., Khomutov, A.V., Moskalenko, N.G., Orekhov, P.T. 2012. Active layer and permafrost boreholes along the Yamal transect. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Matyshak, G.V. 2012. Soils investigations along the EAT. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Orekhov, P., Leibman, M.O. 2012. General Environment and Climate of the EAT. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Raynolds, M.K., Walker, D.A., Kofinas, G.P., Ambrosius, K.J. 2012. Sixty years of landscape change within an Artic Oilfield, Prudhoe Bay, Alaska. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Ukraintseva, N.G., Korobova, T.A. 2012. Summary of willow studies in the Bovanenkovo region. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Walker, D.A. 2012. Summary of the Greening of the Arctic Project. *Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20*. PDF

Walker, D.A., Webber, P.J., Brown, J., Raynolds, M.K., Streever, W., Ambrosius, K. 2012. The evolution of the Integrated Geobotanical and Historical Change Mapping (IGHCM) approach for documenting landscape change (1949-2010), Prudhoe Bay oil field, AK, USA. *12th International Circumpolar Remote Sensing Symposium. Levi, Finland May 14-18*. PDF

Yu, Q., Epstein, H.E., Walker, D.A., Forbes, B.C. 2012. Dynamics of Circum-Arctic Tundra Plant Communities in Response to Climate Warming and Grazing Pressure. *IPY 2012 From Knowledge to Action. Montreal, Canada April 22-27*. PDF

2011

Khitun, O.V., Ermokhina, K.A., Leibman, M.O., Khomutov, A.V. 2011. Plant species indicating the depth of active layer on the Bely Island. *Fourth Russian Conference on Geocryology. Moscow, Russia, June 7-9*.

Walker, D.A. 2011. Arctic vegetation along two long bioclimatic transects in North America and Russia. *Fulbright Lecture, Botany Dept., Masarysk University. Brno, Czech Republic March 10*. PDF, PPT

Walker, D.A. 2011. Socio-ecological effects of oil and gas development in the Arctic: Comparison of the Prudhoe Bay, Alaska and Bovanenkova, Russia regions. *Earth Day, 20th Celebration of the Czech Fulbright Commission. American Center, Prague, Czech Republic April 21*. PDF

Walker, D.A., Bienek, P., Bhatt, U.S., Raynolds, M.K., Epstein, H.E., Jia, G.J., Comiso, J.C., Tucker, C.J., Pinzon, J., Liebman, M.O., Forbes, B.C., Kumpula, T. 2011. The Arctic Tundra is a maritime biome. *High latitude trace gas exchanges: the role of ocean-land interactions. Nuuk, Greenland September 19-22*. PDF

Walker, D.A., Kuss, H.P., Kopecky, M., Frost, G.V., Daniëls, F.J.A., Kade, A.N., Vonlanthen, C.M., Raynolds, M.K., Epstein, H.E. 2011. The North American and Eurasia Arctic transects: Using phytosociology and remote sensing to detect vegetation pattern and change. *European Vegetation Survey 20th Workshop. Rome, Italy April 6-9*. PDF

2010

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Climatology and Seasonality of the ice-ocean-atmosphere-terrestrial system on the Yamal. *Presented at: Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Circumpolar arctic tundra vegetation change is linked to sea-ice decline. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 March-2 April*.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Circumpolar Arctic tundra vegetation change is linked to sea-ice decline. *Presented at: State of the Arctic Meeting Miami, Fl March 16-19*. PDF

Comiso, J.C. 2010. State of the Cryosphere in the Arctic. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Drozdov, D.S., Grechichshev, S.E., Malkova, G.V., Korostelev, Y.V. 2010. Yamal Peninsula maps and GIS information. Update on ECI activities and permafrost research on the Yamal. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland 8-10 March 2010*. PDF

Epstein, H.E., Walker, D.A., Raynolds, M.K., et al. 2010. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in Arctic tundra. *Presented at: State of the Arctic Miami, FL 16-19 March*. PDF

Epstein, H.E., Walker, D.A., Raynolds, M.K., et al. 2010. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. *Presented at: IPY Oslo Science Conference Oslo, Norway 8-12 Jun*.

Forbes, B.C., Fauria, M.M., Zetterberg, P., Kumpula, T. 2010. Deciduous shrub growth and the greening of the Arctic in West Siberia. Abstract GC53B-08, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

Forbes, B.C., Murray, M.S., Walker, D.A. 2010. Human dimensions of land-cover and land-use change in the Arctic with a focus on the Yamal Peninsula, Russia. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD April 20-22*. PDF

Forbes, B.C., Stammler, F., Kumpula, T., et al. 2010. High resilience in the Yamal-Nenets social-ecological System, west Siberian Arctic, Russia. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A. 2010. Summary of 2009 field observations and proposed 2010 study plan for Kharp study site, northwest Siberia. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A., et al. 2010. Spatio-temporal trends in vegetation structure and NDVI in Low Arctic northwest Siberia: evidence from the satellite record and ground observations. Abstract GC54A-03, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

Gubarkov, A. 2010. Issues of Yamal Peninsula gas fields development. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Heim, B., Bartsch, A., Boike, J., Hubberten, H.-W. 2010. DUE Permafrost: a spaceborne permafrost monitoring and information system. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Jia, G.J., Hu, Y., Wang, H., et al. 2010. Greening and Seasonality: Multi-scale Approaches. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland 8-10 March 2010*. PDF

Kaplan, J.O., Melton, J.R., Pfeiffer, M., Collins, P.M. 2010. Large-scale dynamic modeling of soil-vegetation interactions. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*.

Khitun, O.V., Moskalenko, N.G. 2010. Summary of Yamal vegetation and flora. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Khomutov, A.V., Leibman, M.O. 2010. Landscape pattern and cryogenic landsliding hazard analysis at VaskinyDachi, Central Yamal. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*.

Khomutov, A.V., Leibman, M.O., Epstein, H.E. 2010. Relation between active-layer depth, NDVI and LAI along the Yamal Transect. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Kumpula, T., Forbes, B.C., Stammler, F. 2010. Land-use and land-cover changes in Yamal peninsula. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Leibman, M.O., Gubarkov, A.A., Khumotov, A.V., et al. 2010. Geocryological Map of the USSR, 1:2,500,000, 1991. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Orekhov, P., Leibman, M.O. 2010. Yamal Peninsula, climate, zonation, physiography, geology, permafrost. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Pinzon, J.E., Tucker, C.J. 2010. GIMMS 3g NDVI set and global NDVI trends. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Raynolds, M.K., Walker, D.A., Bhatt, U.S., et al. 2010. NDVI trends 1981-2008 in the circumpolar Arctic and Yamal. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Stammler, F. 2010. Humans and animals on northern Yamal: uncovering unknown patterns of movement and settlement..*Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Streletskiy, D.A., Nelson, F.E., Shiklomanov, N.I. 2010. Spatial and temporal variability of active-layer thickness under changing climatic conditions in Northwest Siberia. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Ukraintseva, N.K. 2010. High Willow Shrubs in Yamal: Reasons of Their Wide Expansion and Methods of Biomass Assessment. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Walker, D.A. 2010. Welcome, goals of the workshop, and overview of the project. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Walker, D.A., Epstein, H.E., Bhatt, U.S., et al. 2010. Greening of the Arctic: A planet-to-plant analysis of tundra vegetation change. *Presented at: State of the Arctic Meeting Miami, Fl 16-19 March*. PDF

Walker, D.A., Epstein, H.E., Bhatt, U.S., et al. 2010. Greening of the Arctic: A planet-to-plant analysis of Arctic vegetation change. *Presented at: IPY Oslo Science Conference Oslo, Norway 8-12 June*. PDF

Walker, D.A., Epstein, H.E., Maier, H.A., et al. 2010. The Yamal Transect: Vegetation Analysis and Mapping (a plant to planet approach). *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2010. Controls on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia - an integrative study using ArcVeg and multi-temporal Landsat imagery. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland 8-10 March*. PDF

Yu, Q., Epstein, H.E., Walker, D.A., Frost, G.V. 2010. Modeling dynamics of tundra plant communities on the Yamal Peninsula. Abstract GC54A-04, presented at *Fall Meeting, AGU, San Francisco, CA, 13-17 December*. PDF

2009

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2009. Panarctic linkages between greening of Arctic tundra, sea ice decline, and summer land temperatures. *Presented at: NEESPI Workshop CITIES-2009 Krasnoyarsk, Russia July 14*. PDF

2008

Anon. 2008. Agenda and Abstracts. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Bhatt, U.S., Walker, D.A., Raynolds, M., Comiso, J. 2008. Examining relationships between sea ice and Arctic vegetation on the Pan-Arctic, regional and site scales. Abstract EGU2008-A-11271, presented at *European Geosciences Union General Assembly 2008, Vienna, Austria, 13 -18 April*. 10:EGU2008-A-11271.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2008. Pan-Arctic climate dynamics in relationship to sea ice, land-surface temperatures and NDVI: focus Yamal region & comparison with North America. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Comiso, J.C. 2008. Decadal Changes in the Arctic Sea Ice Cover and Surface Temperature with especial focus on Yamal, Alaska and the Canadian Peninsula. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Drozdov, D.S. 2008. Mapping and remote sensing of natural and technogenicgeosystems in West Siberia. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Epstein, H.E. 2008. Field and Modeling Analyses of Tundra Vegetation Communities Along Latitudinal Temperature Gradients. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Epstein, H.E., Walker, D.A., Kuss, P., Karlejaärvi, E. 2008. (1)LAI, NDVI, and vegetation biomass for Low Arctic sites in the Yamal region of Russia (2)An overview of modeling vegetation and ecosytem dynamics in arctic tundra. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia 28-30 January*.

Forbes, B.C., colleagues, w.m.d. 2008. Effects of petroleum development on reindeer herding in Northwest Siberia: Combining scientific and traditional knowledge. *Presented at: 2008 Yamal Land Cover and Land Use Workshop Moscow, Russia January 28-30*. PDF

Gubarkov, A.A. 2008. Overview of gas and oil development on the Yamal Peninsula. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia 28-30 January*. PDF

Jia, G.J., Wang, H., Epstein, H.E., Walker, D.A. 2008. Greening of Arctic: Knowledge and Uncertainties. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Kaplan, J.O., Lischke, H., Melton, J.R. 2008. Dynamic Modeling of Global Arctic and Subarctic Vegetation. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Khomutov, A.V., Leibman, M.O. 2008. Landscape structure in natural and disturbed conditions of Yamal Peninsula, field results and local GIS. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Kumpula, T. 2008. Remote sensing of land-use/land-cover change in the Bovanenkovo gas field on the Yamal Peninsula. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia 28-30 January*. PDF

Kuss, P., Karlejaärvi, E., Moskalenko, N., et al. 2008. Plant communities at Nadym, Laborovaya, and VaskinyDachi. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia 28-30 January*. PDF

Leibman, M.O. 2008. Welcome. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30, 2008*. PDF

Leibman, M.O., Malkova , G., Khomutov, A., Gubarkov , A. 2008. Overview of Yamal Peninsula with focus on Laborovaya and VaskinyDachi: Climate, zonation, physiography, geology, permafrost. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Matyshak, G.V. 2008. Soils at Nadym and Yamal area. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28*. PDF

Melnikov, V.P., Drozdov, D.S., Malkova, G.V. 2008. Permafrost: contemporary state, stability and dynamics. Technogenic influence. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Moskalenko, N.G. 2008. Overview of vegetation dynamics, disturbance and recovery studies in Nadym and Yamal areas. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Orekhov, P.T. 2008. Lake ecosystems in different landscapes in the Nadym region. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Ponomareva, O.E. 2008. Overview of Nadym Region: Climate, Zonation, Physiography, Geology, Permafrost. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Raynolds, M.K., D.A. Walker, and J.C. Comiso 2008. Spatial patterns of land surface temperature and NDVI and their relation to vegetation distribution on the Yamal Peninsula. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Raynolds, M.K., Walker, D.A. 2008. Circumpolar relationships between permafrost characteristics, NDVI, and arctic vegetation types. *Ninth International Conference on Permafrost, Fairbanks, AK, June 29-July 3*. 2:1469-1474. PDF

Raynolds, M.K., Walker, D.A., Comiso, J.C. 2008. Circumpolar AVHRR Surface Temperature and its Relationship to Bioclimate Zones and NDVI. *Presented at: Komarov Botanical Institute St. Petersburg, Russia February 5*.

Romanovsky, V., Kholodov, A., Marchenko, S. 2008. Pan-Arctic permafrost thermal conditions: Where does the Yamal Peninsula fit?.*Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Stammler, F. 2008. A century of nomadic land use. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Walker, D.A. 2008. Overview of the Yamal LCLUC Project and Objectives of the Meeting. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*. PDF

Walker, D.A. 2008. Application of space-based technologies and models to address land-cover/land-use change problems on the Yamal Peninsula, Russia. *Presented at: 2008 NASA Carbon Cycle and Ecosystems Joint Science Workshop Adelphi, MD April 28 - May 2*. PDF

Walker, D.A., Bhatt, U.S., Epstein, H.E. 2008. Greening of the Arctic: an IPY Initiative. Abstract U23F-05 INVITED, presented at *AGU Fall Meeting, San Francisco, CA, December 12-15*. 89:1. PDF

Walker, D.A., Bhatt, U.S., Romanovsky, V.E., et al. 2008. Application of space-based technologies and models to address land-cover/land-use change problems on the Yamal Peninsula, Russia. Abstract EGU2008-A-05697, presented at *European Geosciences Union General Assembly 2008, Vienna, Austria, April 13-18*. 10:EGU2008-A-05697. PDF

Walker, D.A., Epstein, H.E., Karlejaärvi, E., et al. 2008. 2007 Expedition to Yamal Peninsula Region, Russia. *Presented at: Yamal Land-Cover Land-Use Change Workshop Abstracts Moscow, Russia January 28-30*. PDF

Walker, D.A., Leibman, M.O., Forbes, B.C., Epstein, H.E. 2008. Cumulative effects of rapid climate and land-use changes on the Yamal Peninsula, Russia. Abstract GC52A-07, presented at *AGU Fall Meeting, San Francisco, CA, December 15-19*. 89:GC52A-07. PDF

Yu, Q., Epstein , H. 2008. Modeling Arctic Tundra Vegetation Dynamics in North America and the Yamal Region of Russia. *Presented at: Yamal Land-Cover Land-Use Change Workshop Moscow, Russia January 28-30*.

2007

Alcaraz, D., Chuvieco, E., Epstein, H. 2007. Temporal trends in post-fire regeneration patterns of boreal forests using 1km AVHRR NDVI. Abstract B11D-0777, presented at *AGU Fall Meeting, San Francisco, CA, December 10-14*. 88:5.

2006

Cook, B.I., Bonan, G.B., Levis, S., et al. 2006. Amplification of climate model response to snow cover fraction parameterization through dynamic vegetation. Abstract C21C-1181, presented at *AGU Fall Meeting, San Francisco, CA, December 11-15*. 87:C21C-1181.

Epstein, H.E. 2006. Greening of the Arctic: Assessing tundra dynamics with remote sensing and modeling. *Presented at: Earth System Science Partnership Open Science Conference Beijing, China November 9-12*.

Forbes, B. 2006. Effects of petroleum development on reindeer herding in Northwest Siberia: Combining scientific and traditional knowledge. *Presented at: Earth System Science Partnership Beijing, China November 9-12*.

Raynolds, M.K., Comiso, J.C., Walker, D.A. 2006. Comparison of arctic tundra bioclimate subzones and AVHRR surface temperature, and relationship to NDVI. *Presented at: 9th Bi-Annual Circumpolar Remote Sensing Symposium Seward, Alaska May 16-19*. PDF

Romanovsky, V., Marchenko, S., Brown, J. 2006. Thermal State of Permafrost (TSP): The US Contribution to the International Network of Permafrost Observatories. *Presented at: NEESPI Focus Center Workshop Fairbanks, AK April 6-8*.

Romanovsky, V., Marchenko, S., Duguay, C.R., Walsh, J. 2006. Permafrost dynamics within the Northern Eurasia region and related impacts on surface and sub-surface hydrology. *Presented at: NEESPI Focus Center Workshop Fairbanks, AK April 6-8*.

Romanovsky, V.E., Marchenko, S.S., Grosse, G., et al. 2006. Monitoring and Modeling of the Northern Eurasia Permafrost Dynamics. Abstract GC21B-04 INVITED, presented at *AGU Fall Meeting, San Francisco, CA, December 11-15*. 87:52.

Walker, D.A. 2006. Greening of the Arctic: an IPY initiative. *Presented at: Arctic Science Conference, Arctic AAAS Division Meeting Fairbanks, AK October 2-4*.

Walker, D.A. 2006. Application of space-based technologies and models to address landcover/land-use change problems on the Yamal Peninsula, Russia. *Presented at: NEESPI-CLAC meeting Fairbanks, AK April 6-8*.

Walker, D.A., Daanen, R., Kade, A.N., et al. 2006. Interactions of physical and biological processes in the formation of small patterned-ground features across the arctic climate gradient. *Presented at: Arctic Science Conference, Arctic AAAS Division Meeting Fairbanks, AK October 2-4*.

5.3 Posters

2012

Frost, G.V., Epstein, H.E., Walker, D.A. 2012. Widespread expansion of boreal shrublands in the Siberian Low Arctic since the 1960s. Abstract CC31A-0965, Wednesday Dec. 5, session GC31A, presented at *AGU Fall Meeting. San Francisco, CA December 3-7*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A., Yu, Q. 2012. Expansion and patch dynamics of alder shrublands in the Siberian Low Arctic: evidence from remote-sensing spanning the Space Age. *12th International Circumpolar Remote Sensing Symposium. Levi, Finland May 14-18*. PDF

Khomutov, A. 2012. Mapping of Active Layer Depths Using Correlation between Active Layer Depth and Vegetation Parameters on Central Yamal, Russia. *From Knowledge to Action, 2012 IPY Conference. Montreal, Quebec May 22-27*. PDF

Raynolds, M.K., Walker, D.A., Kofinas, G.P., Ambrosius, K.J. 2012. 60 Years of Landscape Change within an Arctic Oilfield, Prudhoe Bay, Alaska. *12th Circumpolar Remote Sensing Symposium. Levi, Finland 14-18 May*. PDF

Walker, D.A., Epstein, H.E., Bhatt, U.S., Leibman, M.O., Forbes, B.C., Romanovsky, V.E., Kofinas, G., Kumpula, T., Raynolds, M.K., Frost, G.V., Yu, Q., Bieniek, P.A., Orekhov, P., Matyshak, G., Moskalenko, N., Ukraientseva, N., Khumotov, A., Ermokhina, K., Drozdov, D., Comiso, J.C., Pinzon, J., Tucker, C.J., Meschtyb, N., Stammler, F., Khitun, O.V. 2012. Greening of the Arctic Project (IPY-GOA, project ID 569). *From Knowledge to Action, 2012 IPY Conference. Montreal, Quebec May 22-27*. PDF

Walker, D.A., Epstein, H.E., Bhatt, U.S., Leibman, M.O., Forbes, B.C., Romanovsky, V.E., Kofinas, G., Kumpula, T., Raynolds, M.K., Frost, G.V., Yu, Q., Bieniek, P.A., Orekhov, P., Matyshak, G., Moskalenko, N., Ukraientseva, N., Khumotov, A., Ermokina, K., Comiso, J.C., Pinzon, J., Tucker, C.J., Meschtyb, N., Stammler, F. 2012. A hierarchical analysis of land-cover and land-use change in tundra environments: Remote sensing, ground-based observations of social and ecological factors, and models. *2012 NASA LCLUC Science Team meeting. Rockville, MD 3-5 April*. PDF

Walker, D.A., Matyshak, G., Frost, G.V., Zhurbenko, M., Afonina, O. 2012. High cover, biomass, and NDVI of biological soil crusts on Hayes Island, Franz Josef Land, Russia. *Tenth International Conference on Permafrost. Salekhard, Russia June 25-29*. PDF

2011

Bhatt, U.S. 2011. The role of seasonality and large-scale climate drivers in recent Pan-Arctic tundra vegetation variability and change. Abstract GC51F-1075, Friday, Dec. 9, session GC51F, presented at *AGU Fall Meeting. San Francisco, CA, December 5-9*. PDF

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Bieniek, P.A., Epstein, H.E., Jia, G.J., Comiso, J.C., Pinzon, J.E., Tucker, C.J. 2011. Seasonal changes of the ice-ocean-atmosphere-terrestrial system on the Yamal. *LCLUC Science Team Meeting. Adelphi, MD March 28-30*. PDF

Epstein, H.E., Yu, Q., Frost, G.V., Raynolds, M.K., Walker, D.A., Forbes, B.C. 2011. Effects of climate, grazing, and gas development on tundra ecosystems of the Yamal Peninsula, northwestern Siberia. *LCLUC Science Team Meeting. Adelphi, MD* . PDF

Frost, G.V., Epstein, H.E., Walker, D.A., Matyshak, G., Ermokhina, K. 2011. Tall shrub expansion facilitated by patterned ground in the northwest Siberian Low Arctic. Abstract GC51F-1058, Friday, Dec. 9, session GC51F, presented at *AGU Fall Meeting. San Francisco, CA, December 5-9*. PDF

Walker, D.A., Bhatt, U.S., Raynolds, M.K., Bieniek, P.A., Epstein, H.E., Frost, G.V., Leibman, M.O., Forbes, B.C., Comiso, J.C., Tucker, C.J., Pinzon, J. 2011. Satellite and land-based observations of environment, vegetation and NDVI along two Arctic Transects: Partial results from the IPY Greening of the Arctic Project. Abstract GC51F-1072, Friday, Dec. 9, session GC51F, presented at *AGU Fall Meeting. San Francisco, CA, December 5-9*. PDF

Walker, D.A., Raynolds, M.K., Epstein, H.E., Bhatt, U.S., Frost, G.V., Jia, G.J., Comiso, J.C., Pinzon, J.E., Tucker, C.J. 2011. Greening of the Arctic: Spatial variation of biomass and NDVI along two Arctic transects and the Circumpolar Arctic. *LCLUC Science Team Meeting. Adelphi, MD March 28-30*. PDF

Yu, Q. 2011. Modeling dynamics of circum-arctic tundra plant communities in response to climate warming and grazing pressure. Abstract GC41C-0831, Friday, Dec. 9, session GC51F, presented at *AGU Fall Meeting. San Francisco, cA, December 5-9*. PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2011. Modeling dynamics of tundra plant communities on the Yamal Peninsula. *LCLUC Science Team Meeting. Adelphi, MD March 28-30*. PDF

2010

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Seasonality of the atmosphere-ocean-ice-terrestrial environment of Arctic tundra. *Presented at: State of the Arctic Conference Miami, FL March 16-19*. PDF

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Climatology and variability of the ice-ocean-atmosphere-terrestrial system on the Yamal. *Presented at: NASA Land-Cover and Land-Use Change Science Team Meeting Bethesda, MD April 20-22*. PDF

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2010. Circumpolar arctic tundra vegetation change is linked to sea-ice decline. *Presented at: Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Epstein, H.E., Walker, D.A., Raynolds, M.K., et al. 2010. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 20-22 April*. PDF

Forbes, B.C., Fauria, M.M., Zetterberg, P. 2010. Russian Arctic Warming and 'Greening' are Closely Tracked by Tundra Shrub Willows. *Presented at: State of the Arctic Conference Miami, FL March 16-19*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A. 2010. Spatio-temporal trends in tree and shrub cover in the circumpolar Low Arctic: Evidence from 1960s satellite photography and ground observations. *Presented at: State of the Arctic Meeting Miami, FL March 16-19*.

Frost, G.V., Epstein, H.E., Walker, D.A. 2010. Spatio-temporal dynamics in tree and tall shrub cover near Kharp, northwest Siberia: 2009 field observations and proposed 2010 study plan. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A. 2010. Spatio-temporal dynamics in tree and tall shrub cover near Kharp, northwest Siberia. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD April 20-22*. PDF

Frost, G.V., Walker, D.A., Raynolds, M.K., Epstein, H.E. 2010. Ordination and gradient analysis of Yamal Peninsula releve data. *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland March 8-10*. PDF

Jia, G.J., Epstein, H.E., Walker, D.A., et al. 2010. Satellite view of changing phenological patterns over Arctic tundra biome. *Presented at: State of the Arctic Meeting Miami, FL March 16-19*.

Khitun, O., Rebristaya, O. 2010. Concrete Flora Concept as a Base for Floristic Investigations in the Russian Arctic. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Maier, H.A., Walker, D.A. 2010. Yamal Peninsula, Russia: Landsat TM Mosaic Image (1:1M scale), Land-Cover Maps and NDVI Maps of the LCLUC Study Areas (1:250K-1:300K scales). *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Maier, H.A., Walker, D.A. 2010. OstrovBelyy (White Island), Yamal Peninsula region, Russia: Landsat ETM+ false color image, land-cover map, and NDVI map (1:200K scale). *Presented at: Second Yamal Land-Cover Land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Maier, H.A., Walker, D.A. 2010. Application of Global Land Survey data to land-cover mapping: Yamal Peninsula, Russia. *Presented at: NASA Land-Cover and Land-Use Change Science Team Meeting Bethesda, MD April 20-22*. PDF

Moskalenko, N.G. 2010. Vegetation Dynamics at the Nadym and Kharasavei sites in the West Siberia North. *Presented at: Yamal Land-Cover land-Use Change Workshop Rovaniemi, Finland March 08-10*. PDF

Walker, D.A., Epstein, H.E., Maier, H.A., et al. 2010. The Yamal LCLUC Study: Vegetation analysis and mapping along a 900-km Arctic transect. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 20-22 April*. PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2010. Land surface dynamics on the Yamal Peninsula based on multi-temporal imagery. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD April 20-22*.

2009

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2009. Seasonality of the air-sea-ice-land environment of Arctic tundra in Northern Eurasia and North America. Abstract GC31A-0701, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0701. PDF

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al. 2009. Greening of Arctic tundra is linked to warming summer land temperatures and sea-ice declines. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 March - 2 April*. PDF

Epstein, H.E., Walker, D.A., Karlejaärvi, E., et al. 2009. Biomass-NDVI-LAI patterns and relationships on the Yamal Peninsula, Russia. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 Mar-2 Apr*. PDF

Epstein, H.E., Walker, D.A., Raynolds, M.K., et al. 2009. Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra. Abstract GC31A-0697, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0697. PDF

Frost, G.V., Epstein, H.E., Jorgenson, M.T. 2009. Spatio-temporal trends in tree and tall shrub cover in the circumpolar Arctic: evidence from repeat ground photographs and 1960s satellite imagery. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 March - 2 April*. PDF

Frost, G.V., Epstein, H.E., Walker, D.A. 2009. Spatio-temporal trends in tree and tall shrub cover in the Eurasian Low Arctic: evidence from 1960s and contemporary satellite imagery and ground observations. Abstract GC31A-0698, presented at *AGU Fall Meeting, San Francisco, CA, December 14-18*. 90:GC31A-0698. PDF

Jia, G.J., Epstein, H.E., Walker, D.A., et al. 2009. Decadal changes of phenological patterns over Arctic tundra biome. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 March-2 April*. PDF

Raynolds, M.K., Walker, D.A., Verbyla, D., Huetmann, F. 2009. Modeling the distribution of circumpolar arctic vegetation. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, Maryland 31 March-2 April*. PDF

Walker, D.A., Leibman, M.O., Epstein, H.E., et al. 2009. Vegetation greenness on the Yamal Peninsula, Russia: Disturbance-climate-change interactions. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 March-2 April*. PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2009. Simulating soil organic nitrogen and grazing effects on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia. *Presented at: Land Cover, Land Use Change Spring Science Team Meeting Bethesda, MD 31 March-2 April*. PDF

Yu, Q., Epstein, H.E., Walker, D.A. 2009. Evaluating Environmental Controls on Arctic Tundra Vegetation Dynamics on Yamal Peninsula, Russia. *Presented at: EnviroDay University of Virginia, VA January 12*. PDF

2008

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2008. Application of Space-based Technologies and Models to Address Land-cover/Land-use Change Problems on the Yamal Peninsula, Russia: Circumpolar and regional analysis of the relationship between sea-ice variability, summer land-surface temperatures, Arctic t. *NASA Carbon Cycle and Ecosystems Joint Science Workshop, Adelphi, MD, April 28 - May 2*. PDF

Epstein, H.E., Walker, D.A., Kuss, P., et al. 2008. Ecosystem Properties along a Latitudinal Gradient of the Yamal Region, Russia. Abstract EGU2008-A-04406, presented at *European Geosciences Union General Assembly, Vienna, Austria, 13 - 18 April*. 10:EGU2008-A-04406. PDF

Forbes, B.C., Stammler, F., Pajunen, A., Karlejaärvi, E. 2008. Cumulative Effects of Industrial Development, Reindeer Herding, and Climate Change on the Yamal Peninsula, Russia. *Presented at: 2008 NASA Carbon Cycle and Ecosystems Joint Science Workshop Adelphi, MD April 28 - May2*. PDF

Kumpula, T., Forbes, B.C., Stammler, F. 2008. Landscape Change in the Russian Arctic: Ecological Implications of the Petroleum Industry to the Nenets Reindeer Herding in Yamal Peninsula. *Presented at: 2008 Annual Meeting and Arctic Forum Washington, D.C. 13 - 15 May 2008*. PDF

Raynolds, M.K., Walker, D.A., Comiso, J.C. 2008. Spatial Patterns of Land Surface Temperature and NDVI on the Yamal Peninsula, Russia. *Presented at: NASA Carbon Cycle and Ecosystems Joint Science Workshop Adelphi, MD April 28 - May 2*. PDF

Walker, D.A., Epstein, H.E., Karlejaärvi, E., et al. 2008. Application of space-based technologies and models to address land-cover/land-use change problems on the Yamal Peninsula, Russia: 2007 field studies along the bioclimate gradient. *Presented at: 2008 NASA Carbon Cycle and Ecosystems Joint Science Workshop Adelphi, MD April 28 - May 2*. PDF

Walker, D.A., Forbes, B.C., Stammler, F., et al. 2008. Cumulative impacts analysis on the Yamal Peninsula, Russia: A blueprint for a comparative study in Northern Alaska?.*Presented at: 2008 Annual Meeting and Arctic Forum Washington, D.C. 13-15 May* .PDF

Yu, Q., Epstein, H.E. 2008. Evaluating Arctic tundra system resilience to grazing disturbances: A modeling approach. Abstract EGU2008-A-12154, presented at *European Geosciences Union General Assembly 2008, Vienna, Austria, 13 - 18 April*. 10:EGU2008-A-12154. PDF

Yu, Q., Epstein, H.E. 2008. Evaluating arctic tundra system resilience to grazing disturbances: a modeling approach. *Presented at: NASA Carbon Cycle and Ecosystems Joint Science Workshop Adelphi, Maryland April 28-May 2*. PDF

2007

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2007. The relationship between sea ice variability and arctic tundra on the pan-Arctic, regional, and site scales. Abstract U42C-0612, presented at *AGU Fall Meeting, San Francisco, CA, December 10*. 88:5.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C. 2007. Influence of Regional Sea Ice Variability on Arctic Tundra. *Seventh International Conference on Global Change: Connection to the Arctic, Fairbanks, Alaska, February 19-20*. 76-78. PDF

Jia, G.J., Epstein, H.E., Walker, D.A. 2007. Trends of Vegetation Greenness in the Arctic from 1982-2005. Abstract B21A-0041, presented at *AGU Fall Meeting, San Francisco, CA, December 10-14*. 88:5. PDF

Raynolds, M.K. 2007. The relationship between permafrost characteristics and the distribution of arctic vegetation types. *Presented at: Arctic Science Conference, Arctic AAAS Division Meeting Anchorage, AK 24-26 September*. PDF

2006

Walker, D.A., Bhatt, U.S., Comiso, J.C., et al. 2006. Application of Space-based Technologies and Models to Address Land-cover/Land-use Change Problems on the Yamal Peninsula, Russia. *Presented at: NASA Land-Cover Land-Use Change College Park, MD October 10-12*.

2005

Walker, D.A., Epstein, H.E., Jia, G.J., et al. 2005. Greening of the Arctic: an IPY initiative. *Presented at: ICARP II Copenhagen, Denmark November 10-12*. PDF

6 References cited

Bhatt, U. S., D. A. Walker, M. K. Raynolds, J. C. Comiso, H. E. Epstein, G. Jia, R. Gens, J. E. Pinzon, C. J. Tucker, C. E. Tweedie, and P. J. Webber. 2010a. Circumpolar Arctic Tundra Vegetation Change Is Linked to Sea Ice Decline. Earth Interactions 14:1–20.

Bhatt, U. S., D. A. Walker, M. K. Raynolds, J. C. Comiso, H. E. Epstein, G. Jia, R. Gens, J. E. Pinzon, C. J. Tucker, C. E. Tweedie, and P. J. Webber. 2010b. Circumpolar arctic tundra vegetation change is linked to sea-ice decline. Pages 1–20 *in*. Rovaniemi, Finland.

Bhatt, U. S., D. A. Walker, P. A. Bieniek, M. K. Raynolds, H. E. Epstein, J. C. Comiso, J. Pinzon, and C. J. Tucker. 2012. Drivers of Recent Pan-Arctic Tundra Vegetation Variability and Change. Montreal, Quebec.

Buchhorn, M., and M. Schwieder. 2012. Expedition Eyesight-NAAT-Alaska 2012. Pages 41–65 *in* J. Strauss, M. Ulrich, and M. Buchhorn, editors. Expeditions to Permfrost 2012. Berichte zur Polar und Meeresforschung, Bremerhaven, Germany.

Buchhorn, M., D. A. Walker, B. Heim, M. K. Raynolds, H. E. Epstein, and M. Schweider. 2013. Hyperspectral characterization of Low Arctic tundra vegetation along environmental gradients. Remote Sensing.

Dutrieux, L. P., H. Bartholomeus, M. Herold, and J. Verbesselt. 2012. Relationships between declining summer sea ice, increasing temperatures and changing vegetation in the Siberian Arctic tundra from MODIS time series (2000–11). Environmental Research Letters 7:044028.

Epstein, H. E., D. A. Walker, U. S. Bhatt, P. Bieniek, J. Comiso, J. Pinzon, M. K. Raynolds, C. J. Tucker, G. J. Jia, H. Zeng, I. H. Myers-Smith, B. C. Forbes, D. Blok, M. M. Loranty, P. S. A. Beck, S. J. Goetz, T. V. Callaghan, G. H. R. Henry, C. E. Tweedie, P. J. Webber, A. V. Rocha, G. R. Shaver, and J. M. Welker. (n.d.). Vegetation: Arctic Report Card: Update for 2012.

Epstein, H. E., M. D. Walker, F. S. I. Chapin, and A. M. Starfield. 2000. A transient, nutrient-based model of arctic plant community response to climatic warming. Ecological Applications 10:824–841.

Epstein, H. E., M. K. Raynolds, D. A. Walker, U. S. Bhatt, C. J. Tucker, and J. E. Pinzon. 2012. Dynamics of aboveground phytomass of the circumpolar Arctic tundra during the past three decades. Environmental Research Letters 7:015506.

Epstein, H. E., Q. Yu, J. O. Kaplan, and H. Lischke. 2007. Simulating future changes in arctic and subarctic vegetation. Computing in Science and Engineering 9:12–23.

Forbes, B. C., and F. Stammler. 2009. Arctic climate change discourse: the contrasting politics of research agendas in the West and Russia. Polar Research 28:28–42.

Forbes, B. C., F. Stammler, T. Kumpula, N. Meschtyb, A. Pajunen, and E. Kaarlejärvi. 2009. High resilience in the Yamal-Nenets social-ecological system, West Siberian Arctic, Russia. Proc. Natl. Acad. Sci. 106:22041–22048.

Forbes, B. C., M. M. Fauria, and P. Zetterberg. 2010. Russian Arctic warming and "greening" are closely tracked by tundra shrub willows. Global Change Biology 1542-1554:1542–1554.

Frost, G. V., H. E. Epstein, D. A. Walker, G. Matyshak, and K. Ermokhina. 2013. Patterned-ground facilitates shrub expansion in Low Arctic tundra. Environmental Research Letters 8:015035.

Frost, G. V., H. Epstein, and D. A. Walker. 2012, December 1. Widespread expansion of boreal shrublands in the Siberian Low Arctic since the 1960s. San Francisco.

Goetz, S. J., H. E. Epstein, J. D. Alcaraz, P. S. A. Beck, U. S. Bhatt, A. Bunn, J. C. Comiso, G. J. Jia, J. O. Kaplan, H. Lilschke, A. Lloyd, D. A. Walker, and Q. Yu. 2011. Recent changes in Arctic vegetation: Satellite observations and simulation model predictions. Pages 9–36 *in* G. Gutman and A. Reissell, editors. Eurasian Arctic Land Cover and Land Use in a Changing Climate. Springer, New York.

Heim, B., M. Buchhorn, and H. W. Hubberten. 2011. YAMAL2011 Expedition 11th July to 9th September, 2011 Part: AWI Data Report 25th July to 9th September, 2011. Alfred Wegener Institute for Polar and Marine Research (AWI) Germany.

Jia, G. J., H. E. Epstein, and D. A. Walker. 2002. Spatial characteristics of AVHRR-NDVI along latitudinal transects in northern Alaska. Journal of Vegetation Science 13:315–326.

Jia, G. J., H. E. Epstein, and D. A. Walker. 2003. Greening of arctic Alaska, 1981-2001. Geophysical Research Letters 30:2067.

Jia, G. J., H. E. Epstein, and D. A. Walker. 2004. Controls over intra-seasonal dynamics of AVHRR NDVI for the Arctic tundra in northern Alaska. International Journal of Remote Sensing 25:1547–1564.

Kaplan, J. O., J. R. Melton, M. Pfeiffer, and P. M. Collins. 2010. Large-scale dynamic modeling of soil-vegetation interactions. Rovaniemi, Finland.

Kasischke, E. S., S. J. Goetz, J. S. Kimball, and M. M. Mack. 2010. The Arctic-Boreal Vulnerabililty Experiment (ABoVE): a concise plan for a NASA-sponsored field campaign. Pages 1–90.

Khomutov, A. V., M. O. Leibman, N. G. Moskalenko, H. E. Epstein, and D. A. Walker. 2009. Numerical characteristics of vegetation and their influence on active layer depth. Pages 81–82 *in*. Sochi, Krasnodar Krai, Russia.

Kumpula, T., A. Pajunen, E. Kaarlejärvi, B. C. Forbes, and F. Stammler. 2011. Land use and land cover change in Arctic Russia: Ecological and social implications of industrial development. Global Environmental Change:1–13.

Kumpula, T., B. C. Forbes, and F. Stammler. 2010. Remote sensing and local knowledge of hydrocarbon exploitation: the case of Bovanenkovo, Yamal Peninsula, West Siberia, Russia. Arctic 63:165–178.

Kumpula, T., B. C. Forbes, F. Stammler, and N. Meschtyb. 2012. Dynamics of a Coupled System: Multi-Resolution Remote Sensing in Assessing Social-Ecological Responses during 25 Years of Gas Field Development in Arctic Russia. Remote Sensing 4:1046–1068.

Leibman, M. O., H. E. Epstein, A. V. Khomutov, N. G. Moskalenko, and D. A. Walker. 2008. Relation of active layer depth to vegetation on the central Yamal Peninsula, Russia. Pages 177–178 *in* D. I. Kane and K. M. Hinkel, editors. Institute of Northern Engineering, University of Alaska Fairbanks, Fairbanks, AK.

Macias-Fauria, M., B. C. Forbes, P. ZETTERBERG, and T. Kumpula. 2012. Eurasian Arctic greening reveals teleconnections and the potential for structurally novel ecosystems. Nature Climate Change 2:613–618.

Maier, H. A., and D. A. Walker. 2010a. Yamal Peninsula, Russia: Landsat TM Mosaic Image (1:1M scale), Land-Cover Maps and NDVI Maps of the LCLUC Study Areas (1:250K-1:300K scales). Rovaniemi, Finland.

Maier, H. A., and D. A. Walker. 2010b. Ostrov Belyy (White Island), Yamal Peninsula region, Russia: Landsat ETM+ false color image, land-cover map, and NDVI map (1:200K scale). Rovaniemi, Finland.

Parmentier, F. J., T. R. Christensen, L. L. Sørensen, S. Rysgaard, A. D. McGuire, P. A. Miller, and D. A. Walker. 2013. The Impact of a Lower Sea Ice Extent on Arctic Greenhouse Gas Exchange. Nature Climate Change 3:195–202.

Raynolds, M. K., and D. A. Walker. 2009. Effects of deglaciation on circumpolar distribution of arctic vegetation. Canadian Journal of Remote Sensing 35:118–129.
Raynolds, M. K., D. A. Walker, G. P. Kofinas, and K. J. Ambrosius. 2012a. 60 Years of Landscape Change within an Arctic Oilfield, Prudhoe Bay, Alaska. Levi, Finland.
Raynolds, M. K., D. A. Walker, H. E. Epstein, J. E. Pinzon, and C. J. Tucker. 2012b. A new estimate of tundra-biome phytomass from trans-Arctic field data and AVHRR NDVI. Remote Sensing Letters 3:403–411.
Raynolds, M. K., D. A. Walker, K. Ambrosius, J. Brown, K. R. Everett, G. P. Kofinas, V. R. Romanovsky, and P. J. Webber. 2013. Cumulative landscape effects of six decades of infrastructure- and climate-related changes in the Prudhoe Bay Oilfield, Alaska
. submitted to the Proceedings of the National Academy of Science.
Raynolds, M. K., F. Huettmann, D. A. Walker, and D. Verbyla. 2011. Modeling environmental controls on Arctic NDVI and effects of predicted changes in climate. Remote sensing of environment.
Raynolds, M. K., J. C. Comiso, D. A. Walker, and D. Verbyla. 2008. Relationship between satellite-derived land surface temperatures, arctic vegetation types, and NDVI. Remote sensing of environment 112:1884–1894.
Stammler, F., and B. C. Forbes. 2007. Declaration on coexistence of oil & gas activities and indigenous communities on Nenets and other territories in the Russian North. Rovaniemi, Finland.
Walker, D. A., H. E. Epstein, M. K. Raynolds, P. Kuss, M. A. Kopecky, G. V. Frost, F. J. A. Daniels, M. O. Leibman, N. G. Moskalenko, G. V. Matyshak, O. V. Khitun, A. V. Khomutov, B. C. Forbes, U. S. Bhatt, A. N. Kade, C. M. Vonlanthen, and L. Tichý. 2011a. NDVI, vegetation, and environmental patterns along two Arctic transects: Initial results from the IPY Greening of the Arctic project. Environmental Research Letters.
Walker, D. A., H. E. Epstein, M. K. Raynolds, P. Kuss, M. A. Kopecky, G. V. Frost, F. J. A. Daniels, M. O. Leibman, N. G. Moskalenko, G. V. Matyshak, O. V. Khitun, A. V. Khomutov, B. C. Forbes, U. S. Bhatt, A. N. Kade, C. M. Vonlanthen, and L. Tichý. 2012a. Environment, vegetation and greenness (NDVI) along the North America and Eurasia Arctic transects. Environmental Research Letters 7:015504.
Walker, D. A., H. E. Epstein, V. E. Romanovsky, C. L. Ping, G. J. Michaelson, R. P. Daanen, Y. Shur, R. A. Peterson, W. B. Krantz, M. K. Raynolds, W. A. Gould, G. Gonzalez, D. J. Nicolsky, C. M. Vonlanthen, A. N. Kade, P. Kuss, A. M. Kelley, C. A. Munger, C. T. Tarnocai, N. V. Matveyeva, and F. J. A. Daniels. 2008. Arctic patterned-ground ecosystems: A synthesis of field studies and models along a North American Arctic Transect. Journal of Geophysical Research 113:G03S01.
Walker, D. A., H. P. Kuss, M. Kopecky, G. V. Frost, F. J. A. Daniels, A. N. Kade, C. M. Vonlanthen, M. K. Raynolds, and H. E. Epstein. 2011b. The North American and Eurasia Arctic transects: Using phytosociology and remote sensing to detect vegetation pattern and change. Rome, Italy.
Walker, D. A., M. K. Raynolds, P. J. Webber, B. JJ, W. Streever, and K. Ambrosius. 2012b. A geoecological mapping approach to examine 60 years (1949-2010) of infrastructure and landscape change in the Prudhoe Bay oil field, Alaska, USA. International Journal of Applied Earth Observation and Geoinformation.
Walker, D. A., M. O. Leibman, H. E. Epstein, B. C. Forbes, U. S. Bhatt, M. K. Raynolds, J. Comiso, A. A. Gubarkov, A. V. Khomutov, G. J. Jia, E. Kaarlejärvi, J. O. Kaplan, T. Kumpula, H. P. Kuss, G. Matyshak, N. G. Moskalenko, P. Orechov, V. E. Romanovsky, N. K. Ukraientseva, and Q. Yu. 2009. Spatial and temporal patterns of greenness on the Yamal Peninsula, Russia: interactions of ecological and social factors affecting the Arctic normalized difference vegetation index. Environmental Research Letters 4:045004.
Walker, D. A., P. J. Webber, B. JJ, M. K. Raynolds, W. Streever, and K. Ambrosius. 2012c. The evolution of the Integrated Geobotanical and Historical Change Mapping (IGHCM) approach for documenting landscape change (1949-2010), Prudhoe Bay oil field, AK, USA. Levi, Finland.
Walker, D. A., P. Kuss, H. E. Epstein, A. N. Kade, C. M. Vonlanthen, M. K. Raynolds, and F. J. A. Daniëls. 2011c. Vegetation of zonal patterned-ground ecosystems along the North America Arctic bioclimate gradient. Applied Vegetation Science 14:440–463.
Walker, D. A., U. S. Bhatt, H. E. Epstein, P. A. Bieniek, J. C. Comiso, G. V. Frost, J. Pinzon, M. K. Raynolds, and C. J. Tucker. 2012d. Changing Arctic tundra vegetation biomass and greenness. In “State of the Climate in 2011” Special Supplement to the Bulletin of American Meteorological Society 93:S138–S139.
Walker, D. A., U. S. Bhatt, T. V. Callaghan, J. C. Comiso, H. E. Epstein, B. C. Forbes, M. Gill, W. A. Gould, G. H. R. Henry, G. J. Jia, S. V. Kokelj, T. C. Lantz, S. F. Oberbauer, J. E. Pinzon, M. K. Raynolds, G. R. Shaver, C. J. Tucker, C. E. Tweedie, and P. J. Webber. 2011d. The Arctic: Land: Vegetation. [In: State of the Climate in 2010]. Bulletin of the American Meteorological Society 92:S150–S152.

Yu, Q., H. E. Epstein, D. A. Walker, G. V. Frost, and B. C. Forbes. 2011. Modeling dynamics of tundra plant communities on the Yamal Peninsula, Russia, in response to climate change and grazing pressure. Environmental Research Letters 6:045505.

Yu, Q., H. Epstein, and D. Walker. 2009. Simulating the effects of soil organic nitrogen and grazing on arctic tundra vegetation dynamics on the Yamal Peninsula, Russia. Environmental Research Letters 4:045027.